

An XMM-ESAS Update

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With plenty of help from

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**NASA/Goddard Space Flight Center and Johns
Hopkins University**

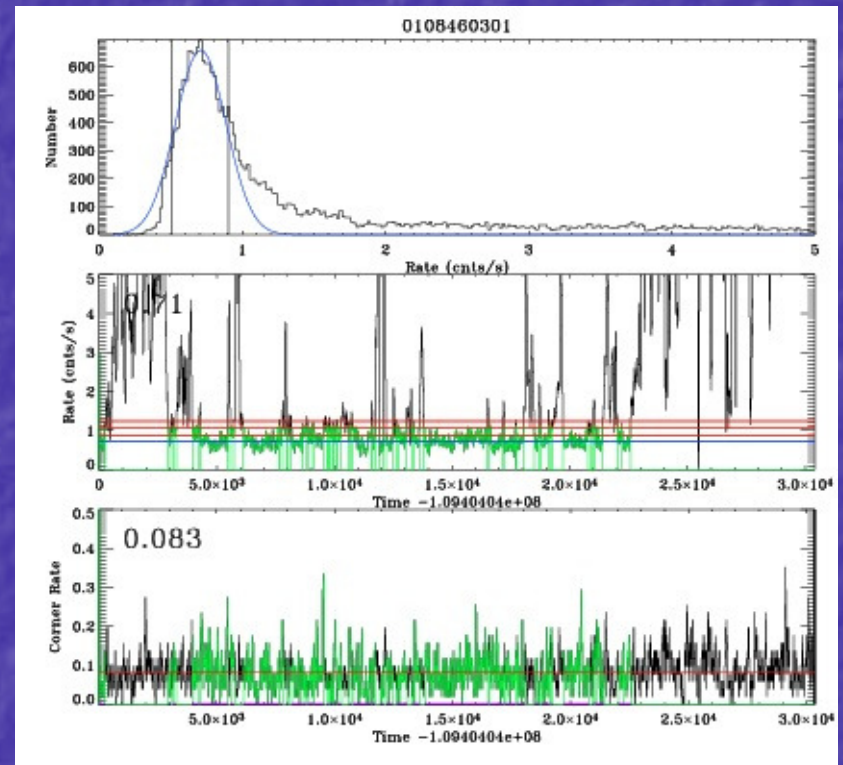
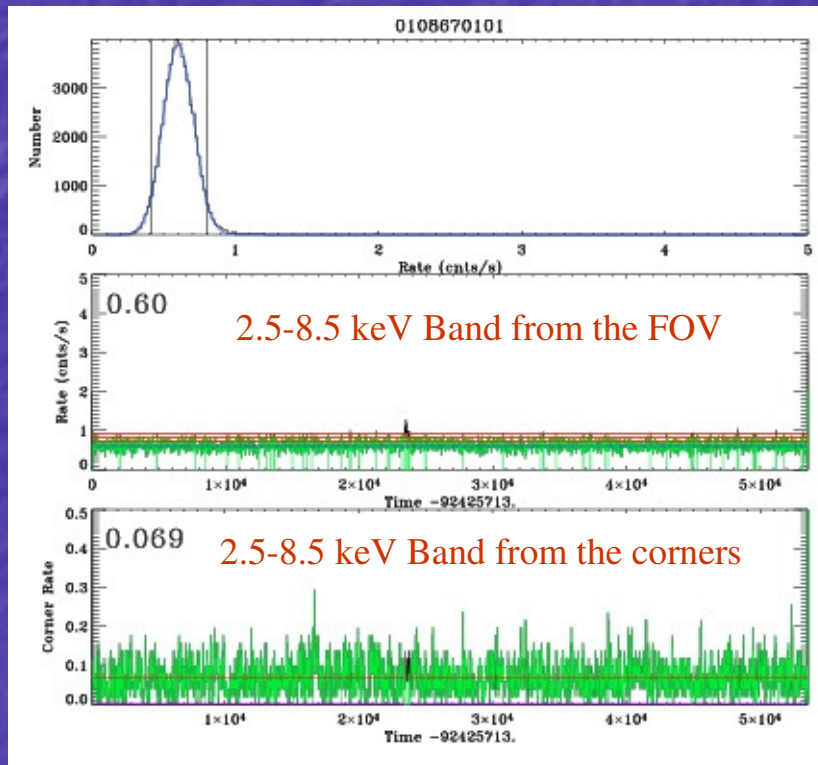
Deterministic Modeling

- Use as many known parameters as possible rather than relying on local background determinations and blank-sky background data sets – which won't work for cosmic background studies
- E.g., FWC Data, RASS, Soft Proton distribution, Archived Observation Data Sets

Step 1 – Filter the Data and Extract Spectra

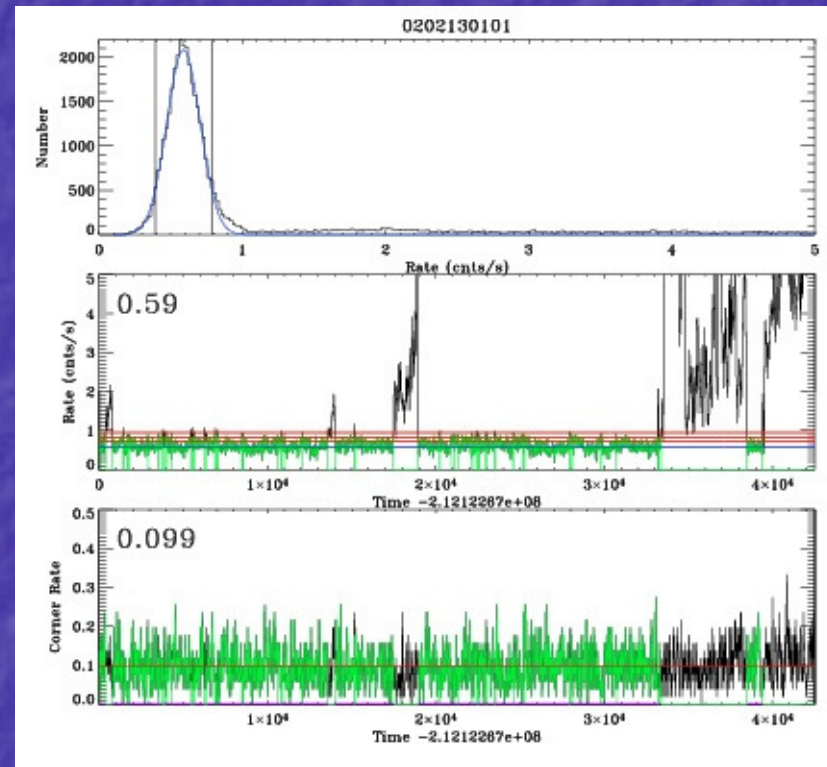
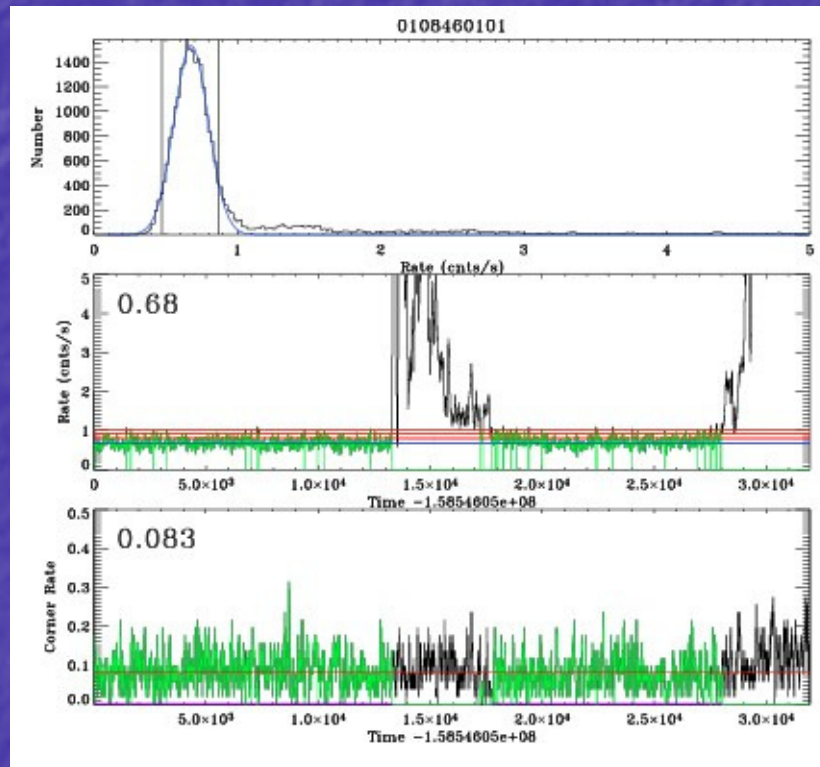
- Nearly any reasonable method will work
 - It is quite likely that there will always be residual soft proton contamination so perfection is not required
 - Any variations significantly above statistics will be seen in most any band
- XMM-ESAS uses the 2.5-8.5 keV band for the filtering – but the new `esfilt` task allows the level to be set by the user
- Create a light curve and then a light-curve histogram
- Fit a Gaussian to the main peak
- Exclude time periods where the count rate is greater than $n\sigma$ times the RMS above the mean of the Gaussian

Step 1 – Filter the Data and Extract Spectra



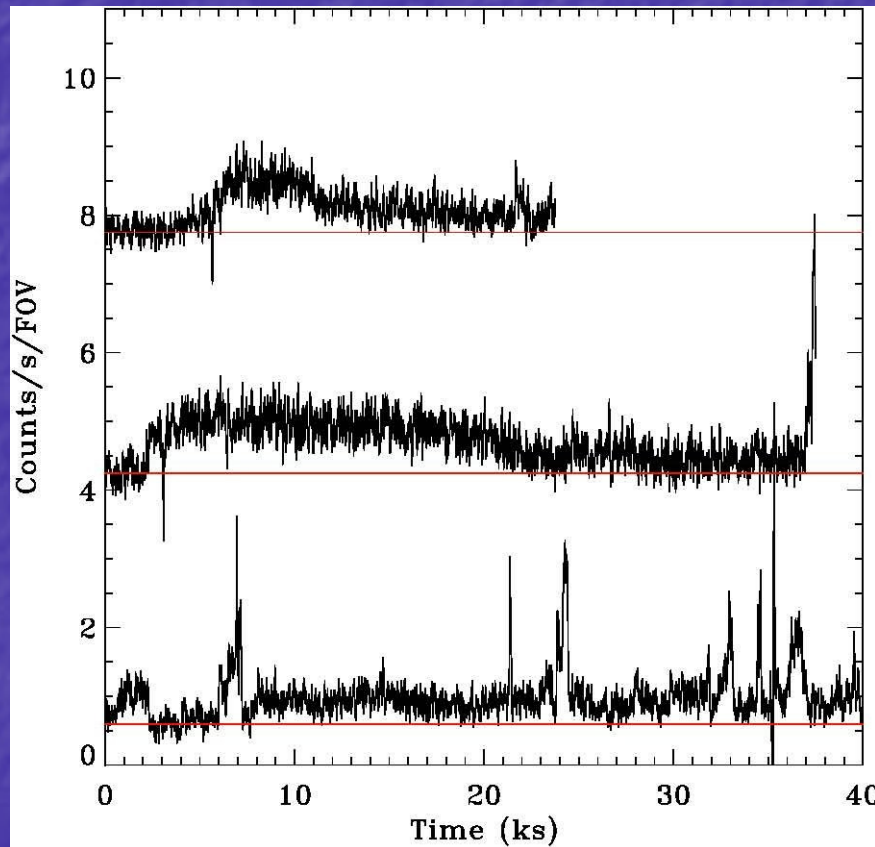
Light curves can range from very clean to incredibly ugly, some with very little or no useful exposure

Step 1 – Filter the Data and Extract Spectra



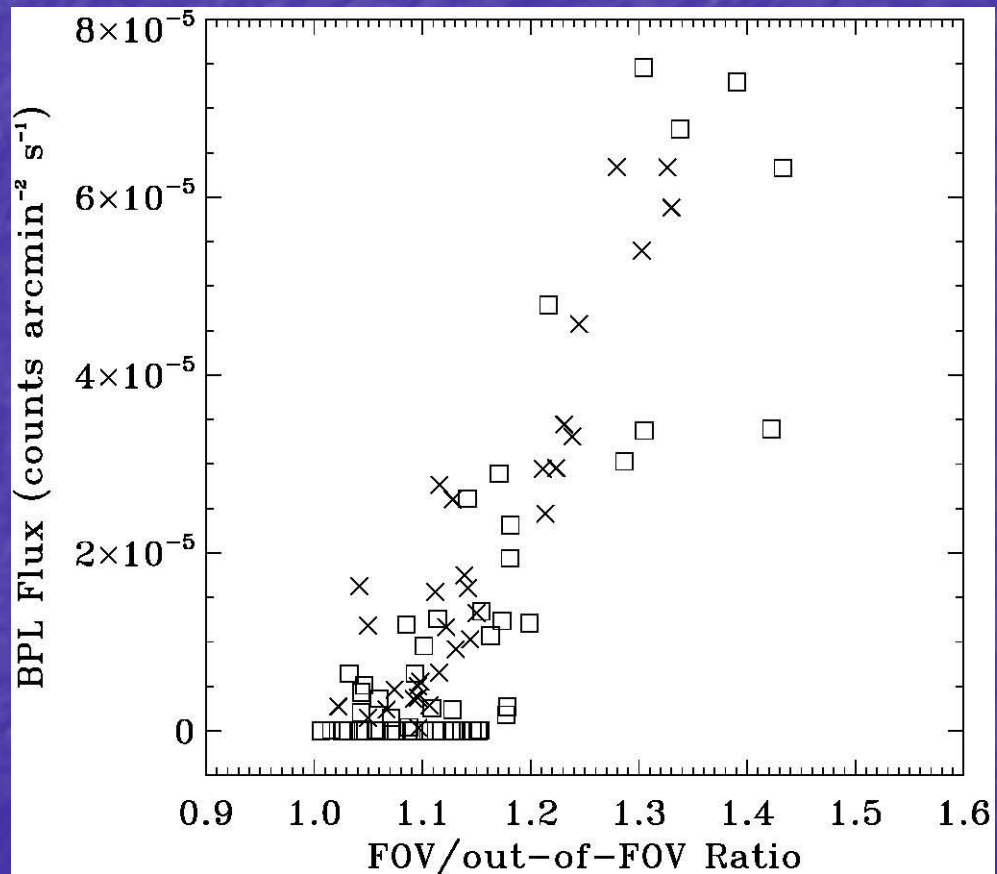
But most of the time the light curve will be somewhere in between.

Step 1 – Filter the Data and Extract Spectra



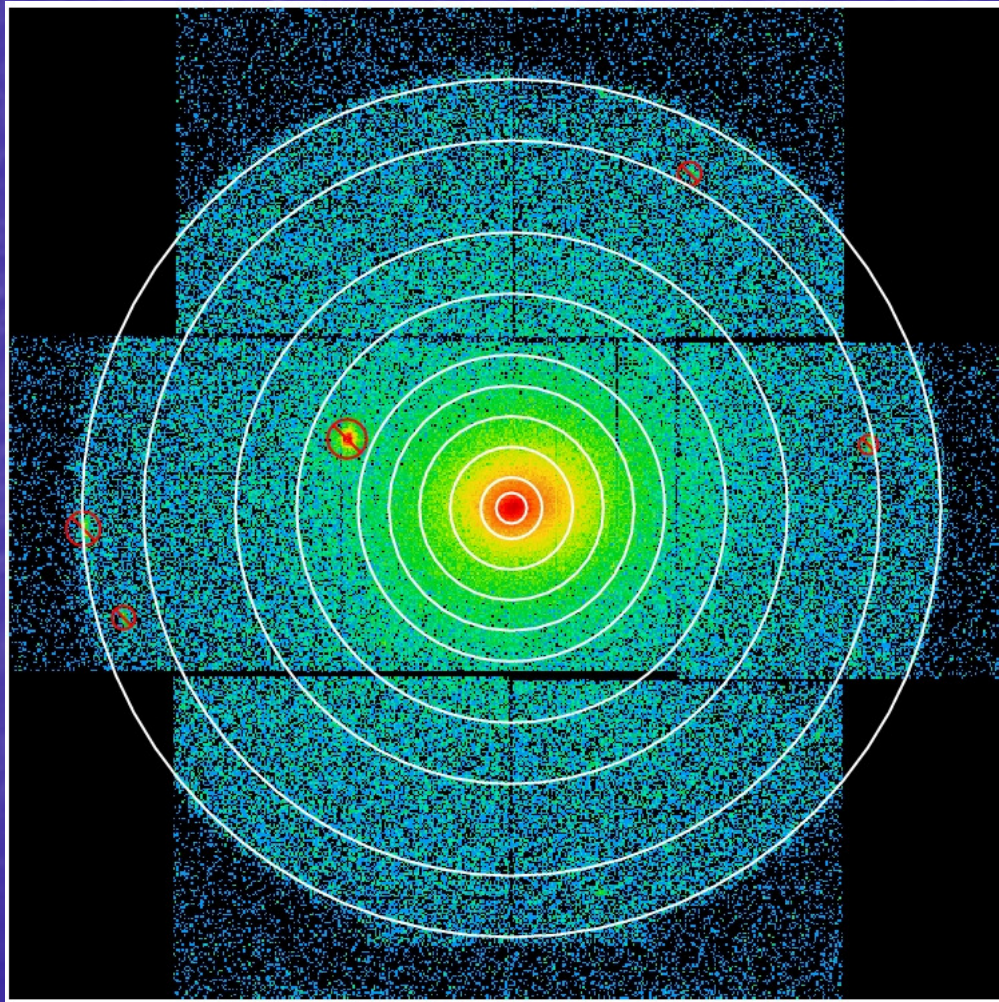
Soft proton contamination can be very problematic with relatively long periods of significant count rates that are relatively stable, and therefore not readily identifiable. The plots here show periods of over 10 ks where the constancy of the light curves, were no additional data available, would suggest that the data were clean.

Step 1 – Filter the Data and Extract Spectra



Comparing the de Luca and Molendi ratio criteria (8-12 keV band) and the fitted flux for screened observations does aid in the identification of observations affected by residual contamination.

Step 1 – Filter the Data and Extract Spectra

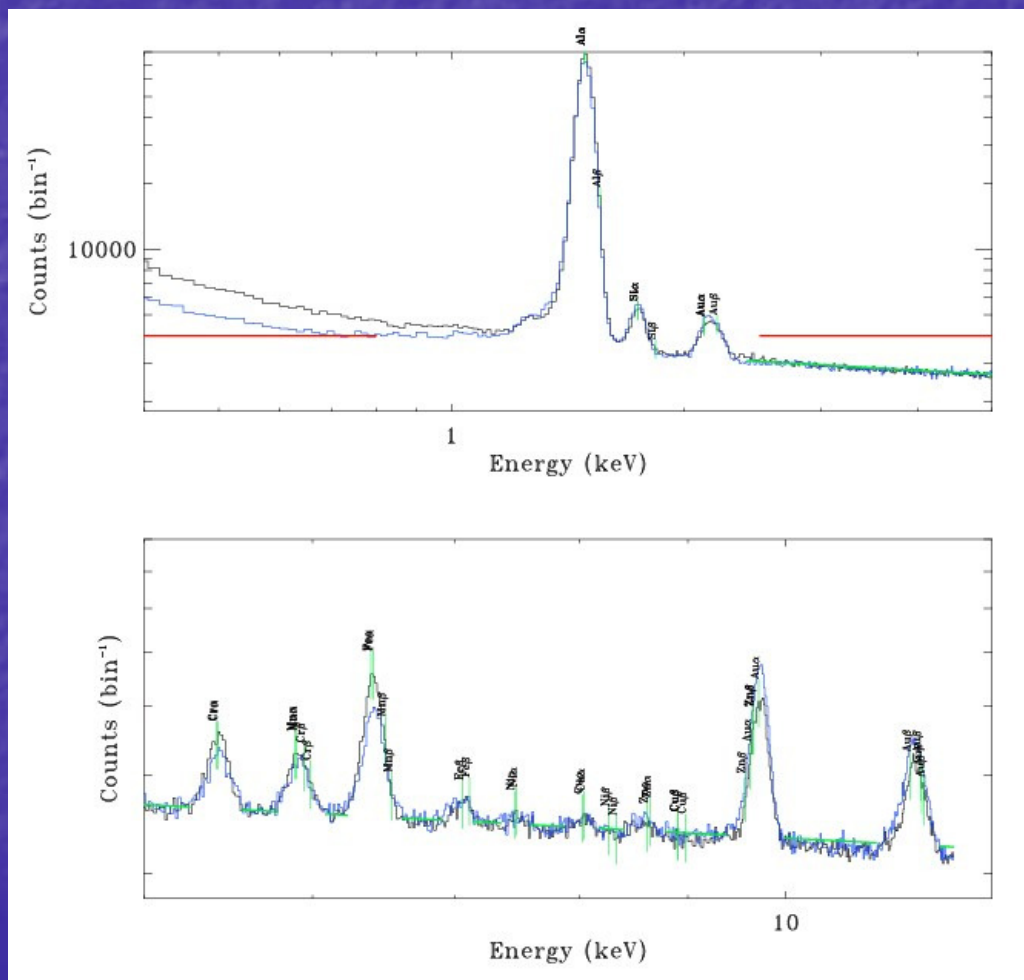


For the cluster analysis, spectra from 10 annuli were extracted after a few bright point sources were excluded. Extraction regions must be specified in detector coordinates.

Step 2 – Model the Quiescent Particle Background

- Determine the corner spectral parameters: high-energy power law slope [2.4-12.0 keV] and hardness ratio [(2.5-5.0)/(0.4-0.8)] from the observation data set
- Search a archived-observation data base for observations with similar parameters
- Augment the observation data set corner spectra with data from the archived-observation data base
- Scale the FWC spectra (treat each CCD separately) for the region of interest by the ratio of the augmented observation corner spectra to the FWC corner spectra
- Use the corner spectra from the outside CCDs to model the background for the central CCD

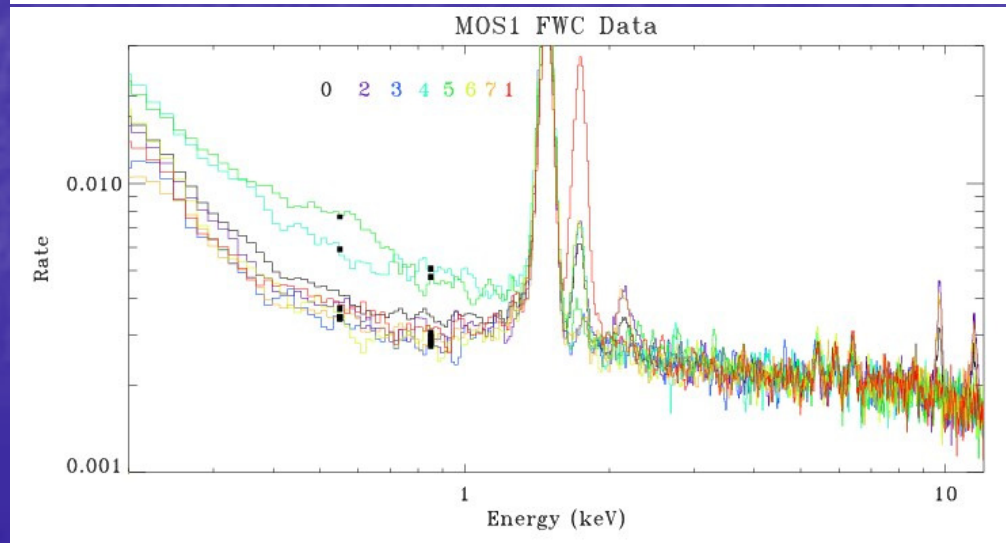
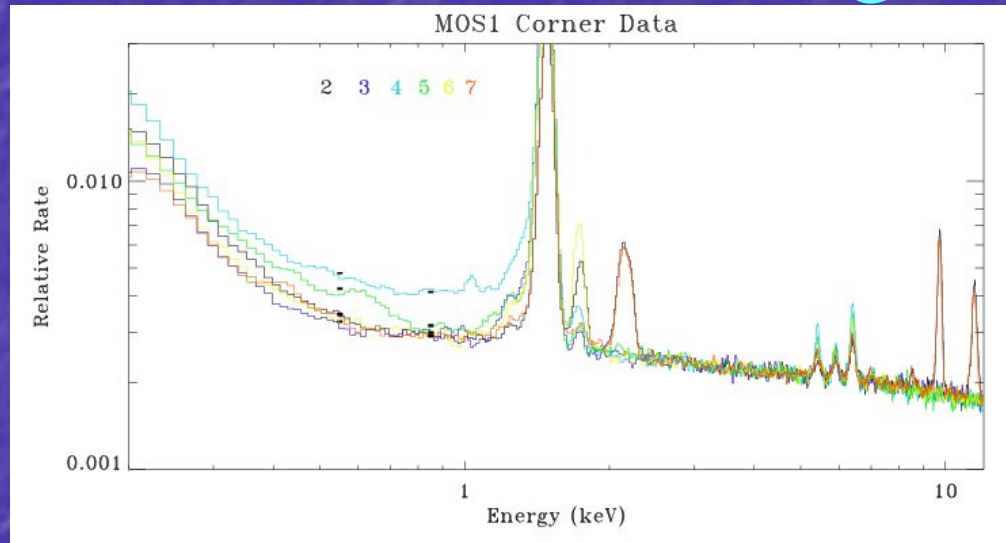
Step 2 – Model the Quiescent Particle Background



The mean quiescent particle background spectrum derived from the corner pixel data in two spectral regions: 0.2-5.0 keV and 5-12.5 keV

- Both continuum and line contributions are both position and temporally varying

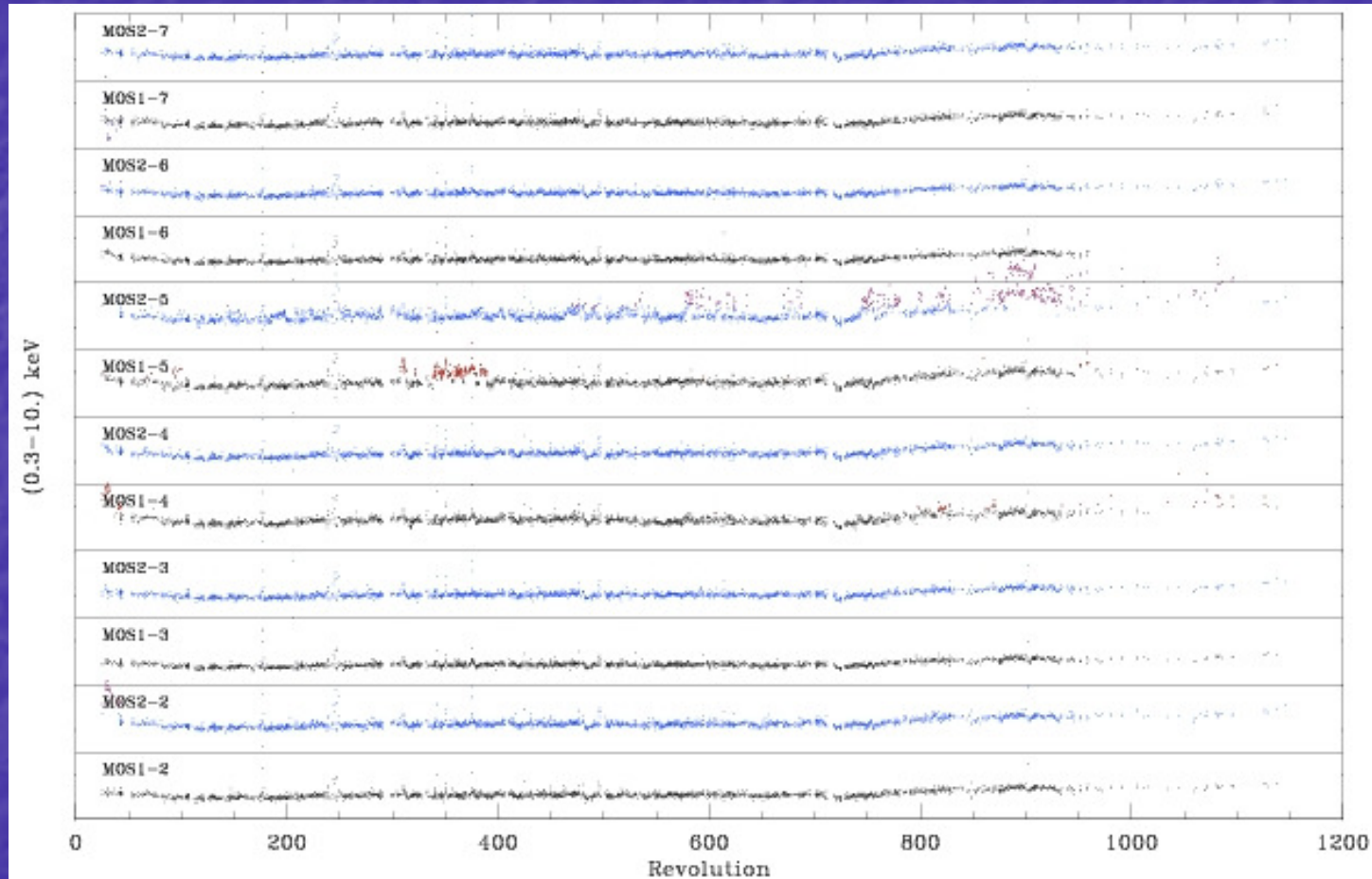
Step 2 – Model the Quiescent Particle Background



The mean “nominal” spectra from the corners and field of view from the MOS1 CCDs. The spectra have been normalized in the 2.5-9.5 keV band. The vertical black bands indicate the uncertainty in the continuum level in 0.3 keV wide regions.

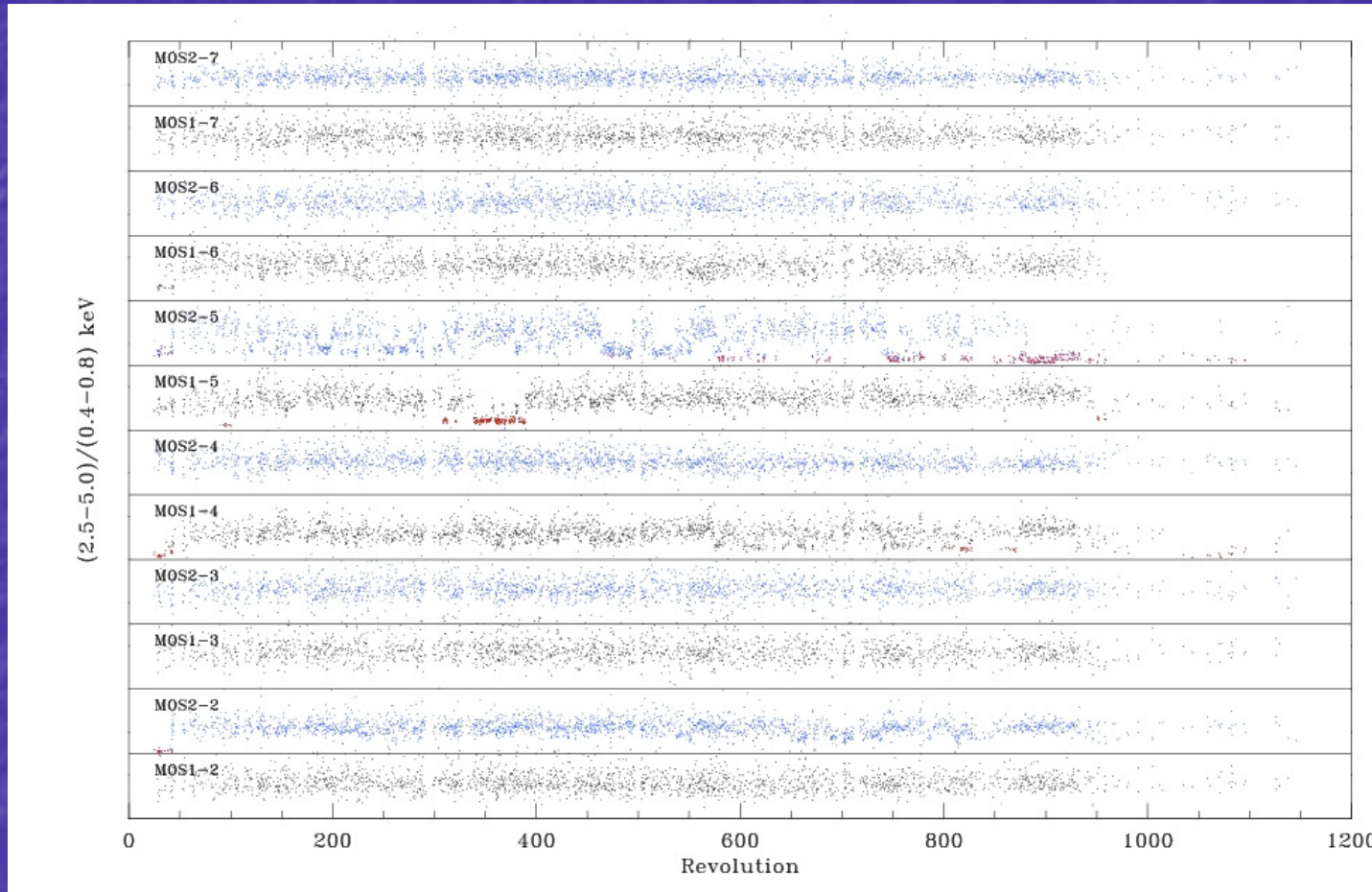
- The corner quiescent particle background spectra differ significantly from those in the field of view

Step 2 – Model the Quiescent Particle Background



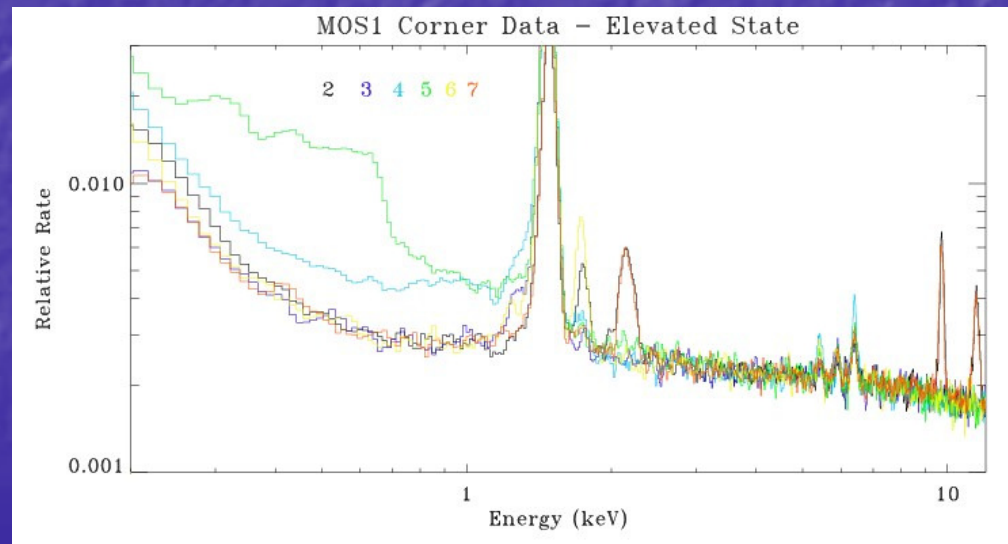
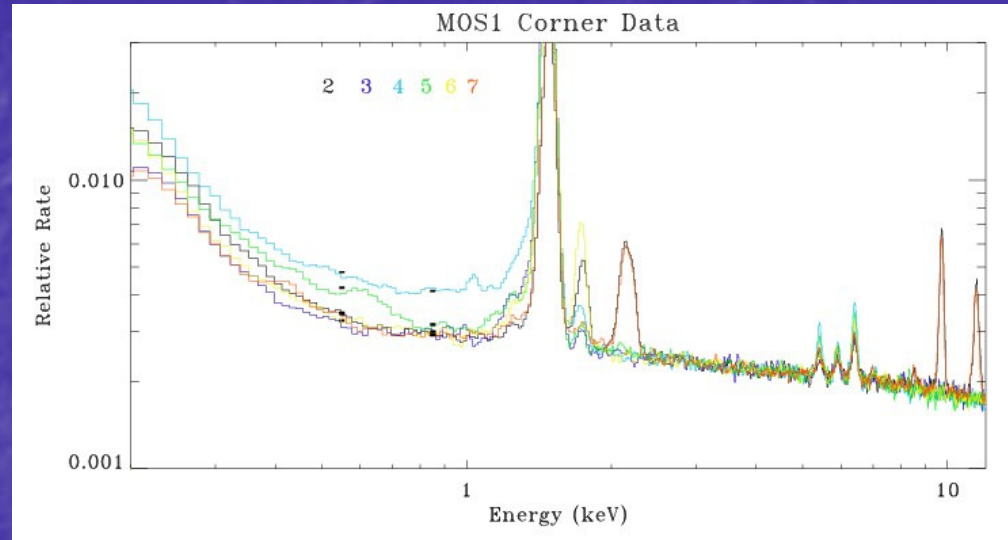
Temporal variation of the 0.3-10.0 keV count rate from the CCD corners

Step 2 – Model the Quiescent Particle Background



Temporal variation of the $(2.5-5.0)/(0.4-0.8)$ keV ratio from the CCD corners

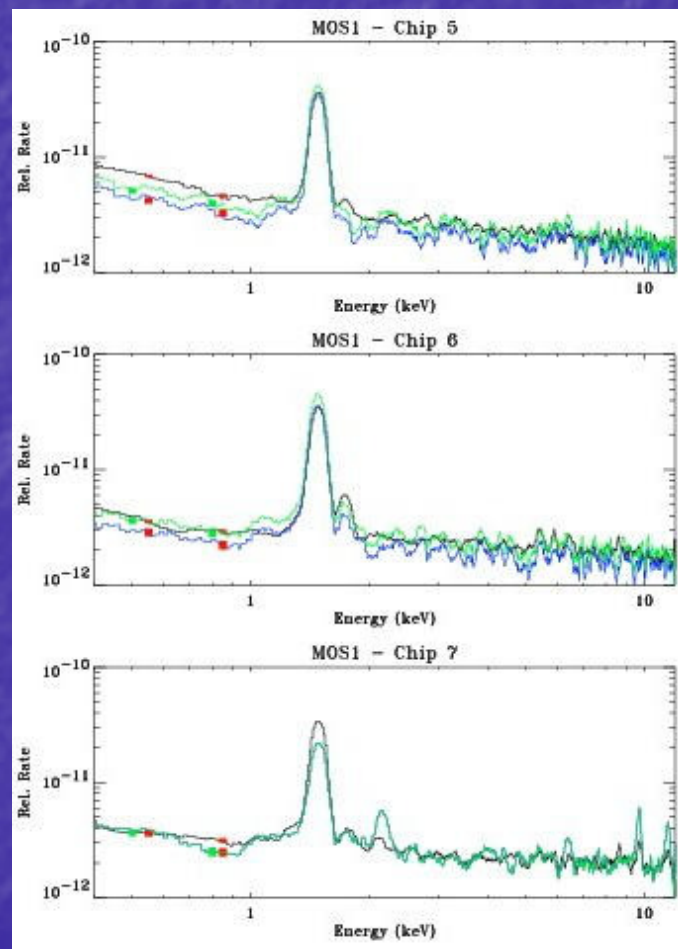
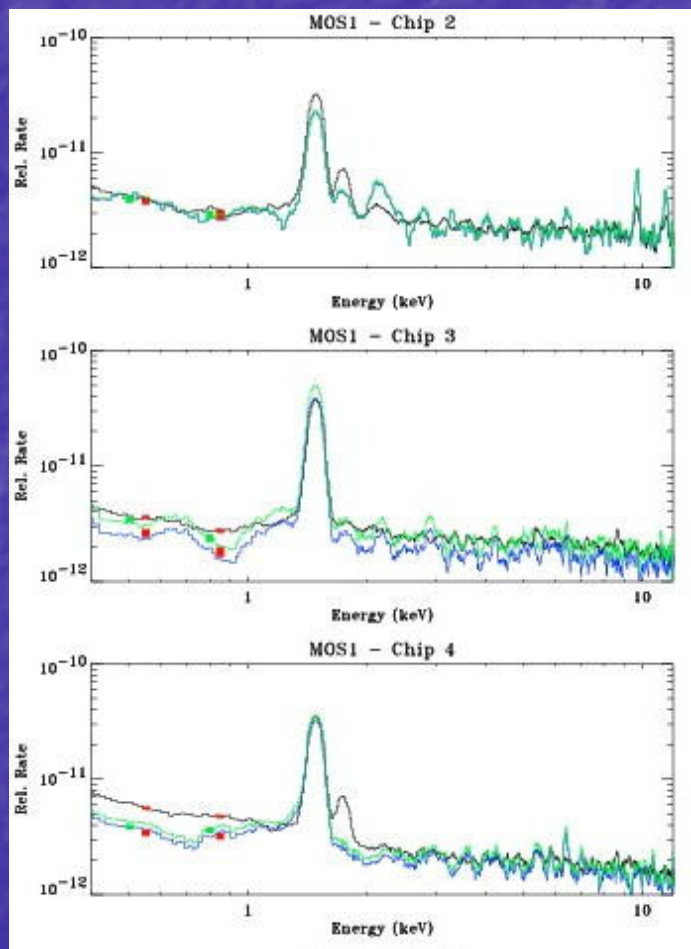
Step 2 – Model the Quiescent Particle Background



“Nominal” and “Elevated” spectra from the corners plotted for the MOS1 CCDs 2-7. The data have again been normalized in the 2.5-9.5 keV band

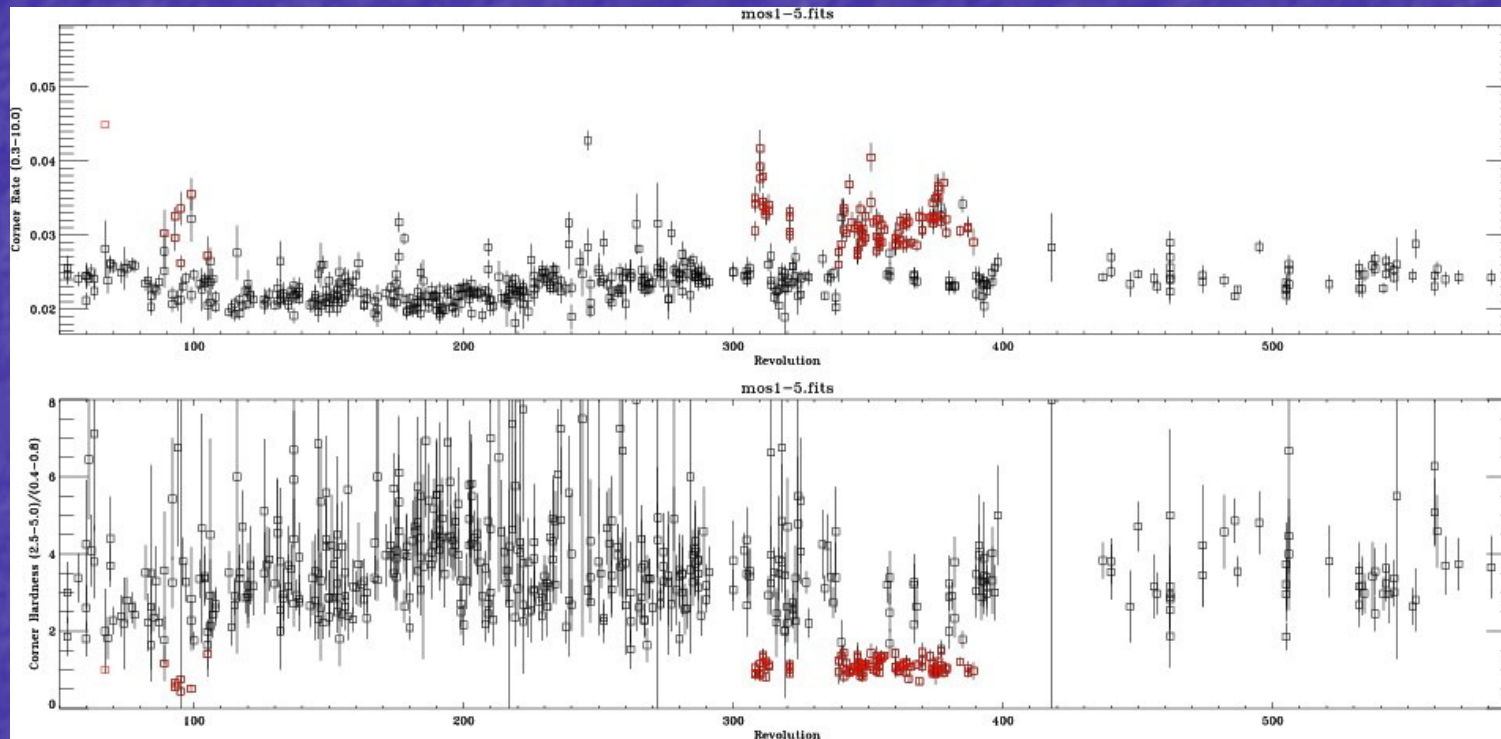
- Occasionally CCDs #2, #4, and #5 go weird, and must be treated separately, and probably excluded. Work remains to be done on this issue.

Step 2 – Model the Quiescent Particle Background



Comparison of the quiescent particle background in the FOV (black line) and corner regions (blue line). The green line is the corner spectrum normalized to the FOV spectrum in the 2.0-10.0 keV band.

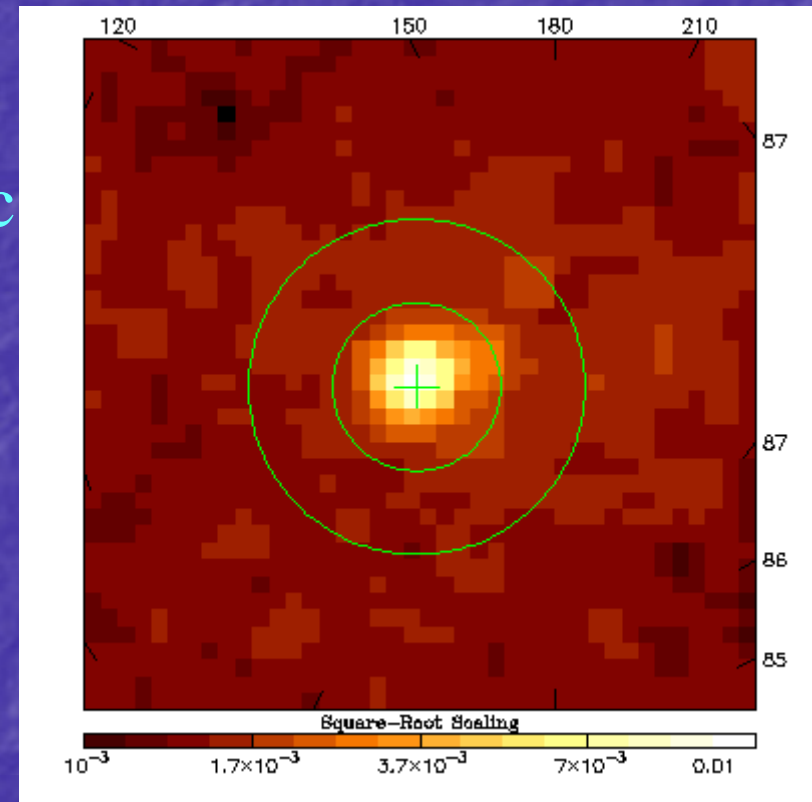
Step 2 – Model the Quiescent Particle Background



The temporal variation of the quiescent particle background measured by MOS1 CCD #5. (Top) the 0.3-10.0 keV band count rate and (bottom) the (2.5-5.0 keV)/(0.4-0.8 keV) band ratio. In red are those observations for which the hardness ratio is <1.5 .

Step 3 – Get the RASS Spectrum for the Area

- Use the HEASARC X-ray Background Tool to create both a spectrum of the cosmic background for the region of interest and to download a ROSAT response matrix
<http://heasarc.gsfc.nasa.gov/cgi-bin/Tools/xraybg/xraybg.pl>
- The X-ray Background Tool has both annuli and cone extraction modes



Coma cluster plot with a 1-2 degree annulus produced by the X-ray Background Tool

Step 4 – Fit the Spectrum

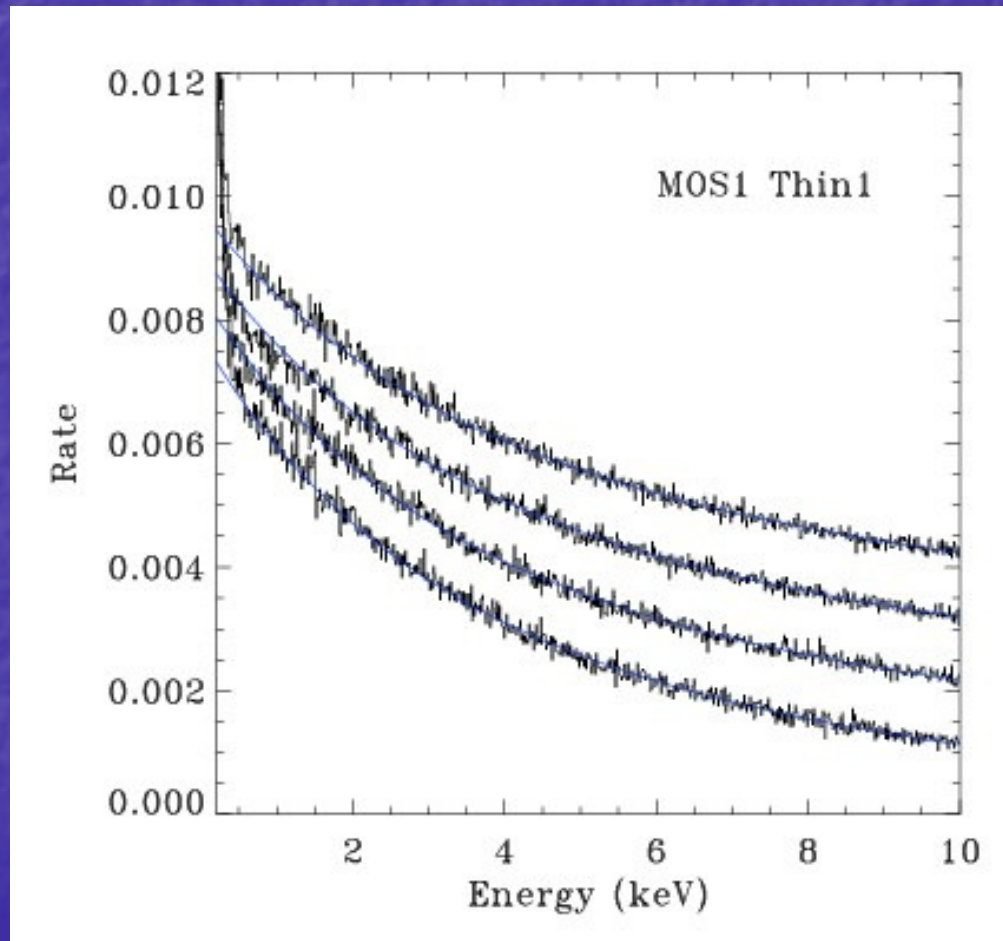
- The model should include (at least) a model for the source of interest, the cosmic background, instrumental Al $K\alpha$ and Si $K\alpha$, a scale factor for the solid angle, and an unfolded power law for any residual soft proton contamination.
- $\text{pow/b} + \text{gauss} + \text{gauss} + \text{con} * (\text{apec} + (\text{apec} + \text{apec} + \text{pow}) * \text{wabs}) + \text{source}$

Step 4 – Fit the Spectrum

Xspec V11: pow/b + gauss + gauss + con*(apec1 + (apec2 + apec3 + pow)*wabs) + source

- pow/b - represents the residual soft proton contamination
- gauss + gauss - are the Al K α and Si K α instrumental lines
- con - scales for the different solid angles (in units of arc minutes)
- apec1 - is the LHB, apec2 - is the soft halo, apec3 - is the hard halo
- pow - is the extragalactic background
- wabs - is the Galactic column density
- source is your favorite source spectrum, for the cluster analysis the model apec*wabs was used

Step 4 – Fit the Spectrum

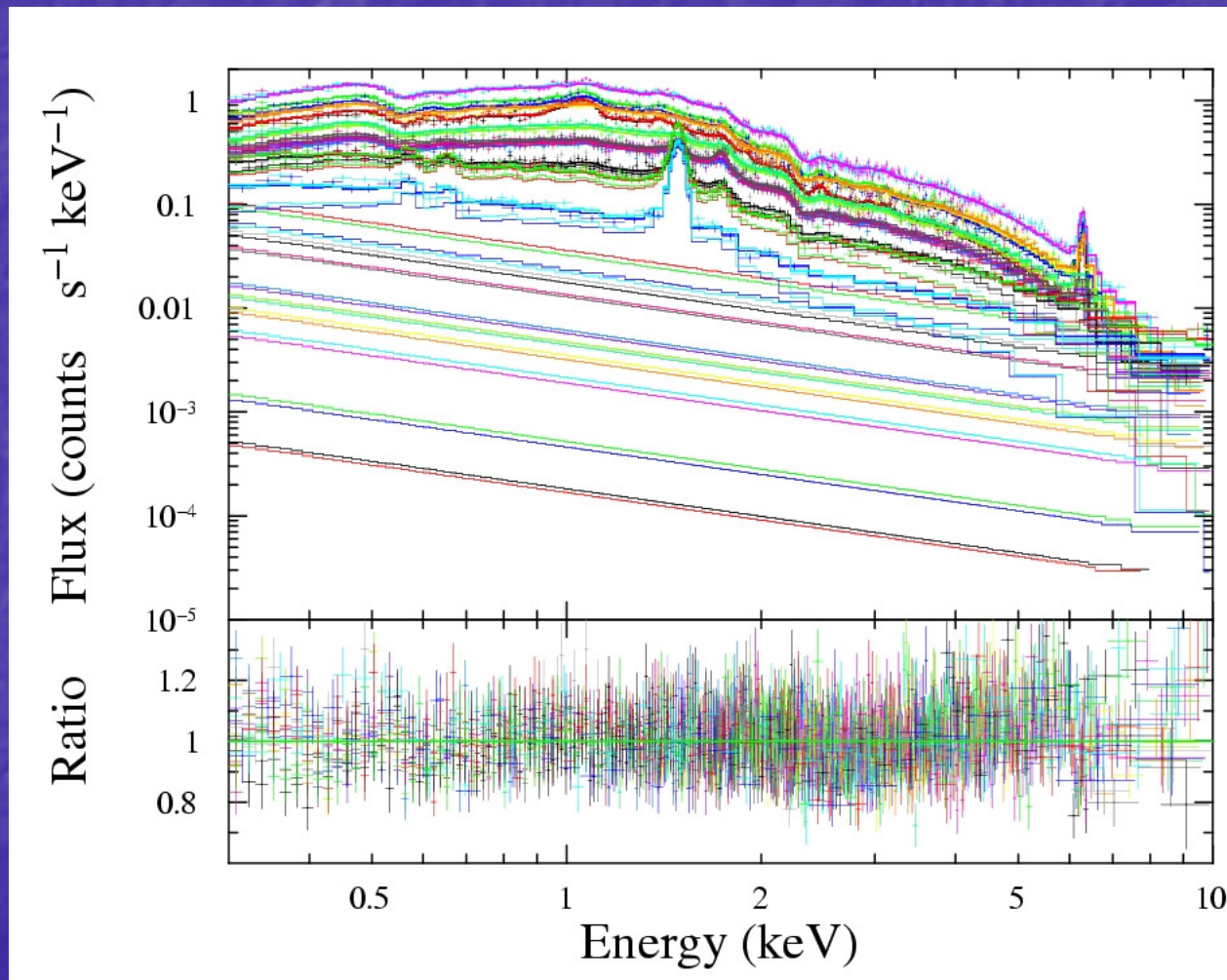


Soft Proton Contamination

Average spectra of the residual soft proton flux from the MOS1 detector with the thin filter. The flare levels are at 1.0-2.0, 2.0-3.0, 3.0-4.0, and 4.0-5.0 counts per second

- The fits here were done using two exponentials. As a practical matter, the cluster analysis used a power law. The power law index is typically in the 0.2-1.5 range

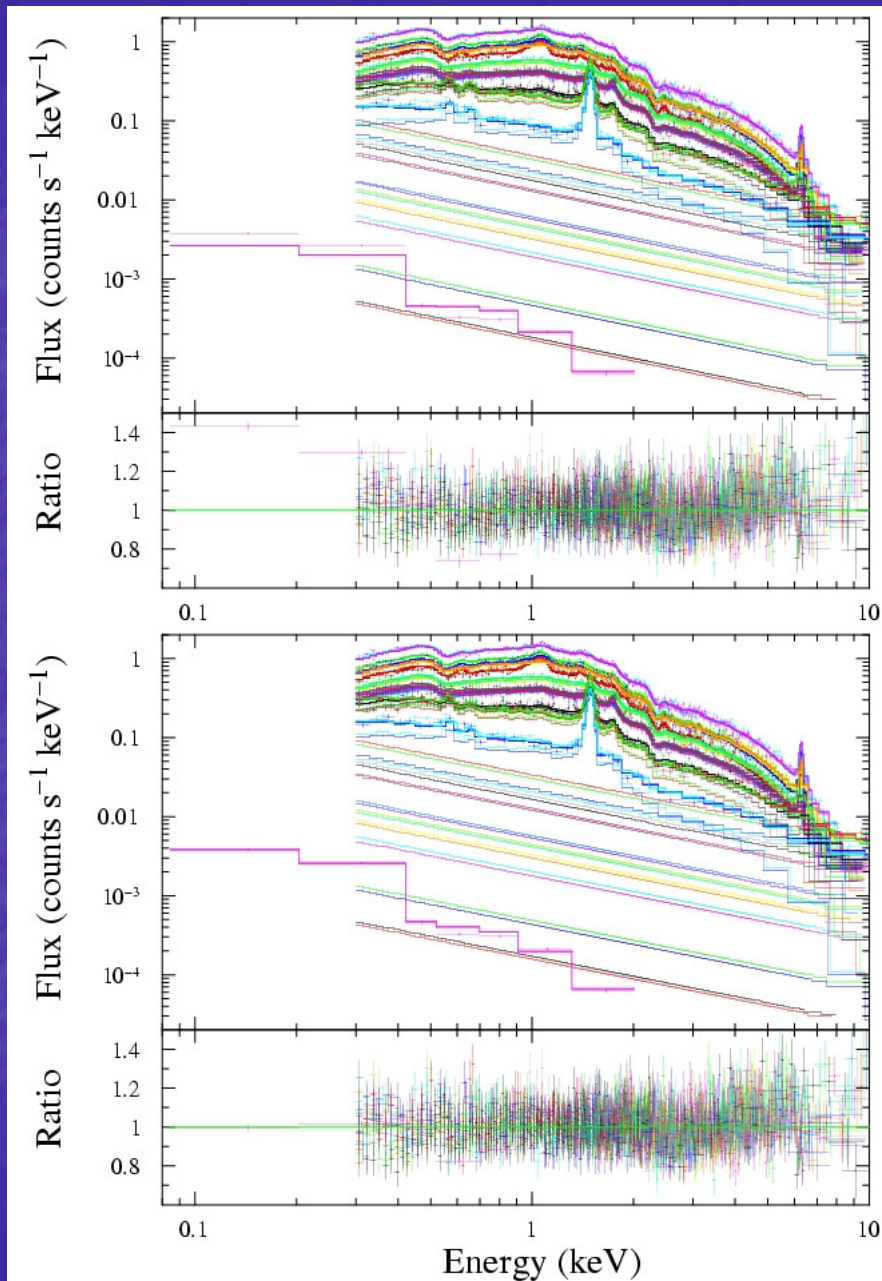
Step 4 – Fit the Spectrum



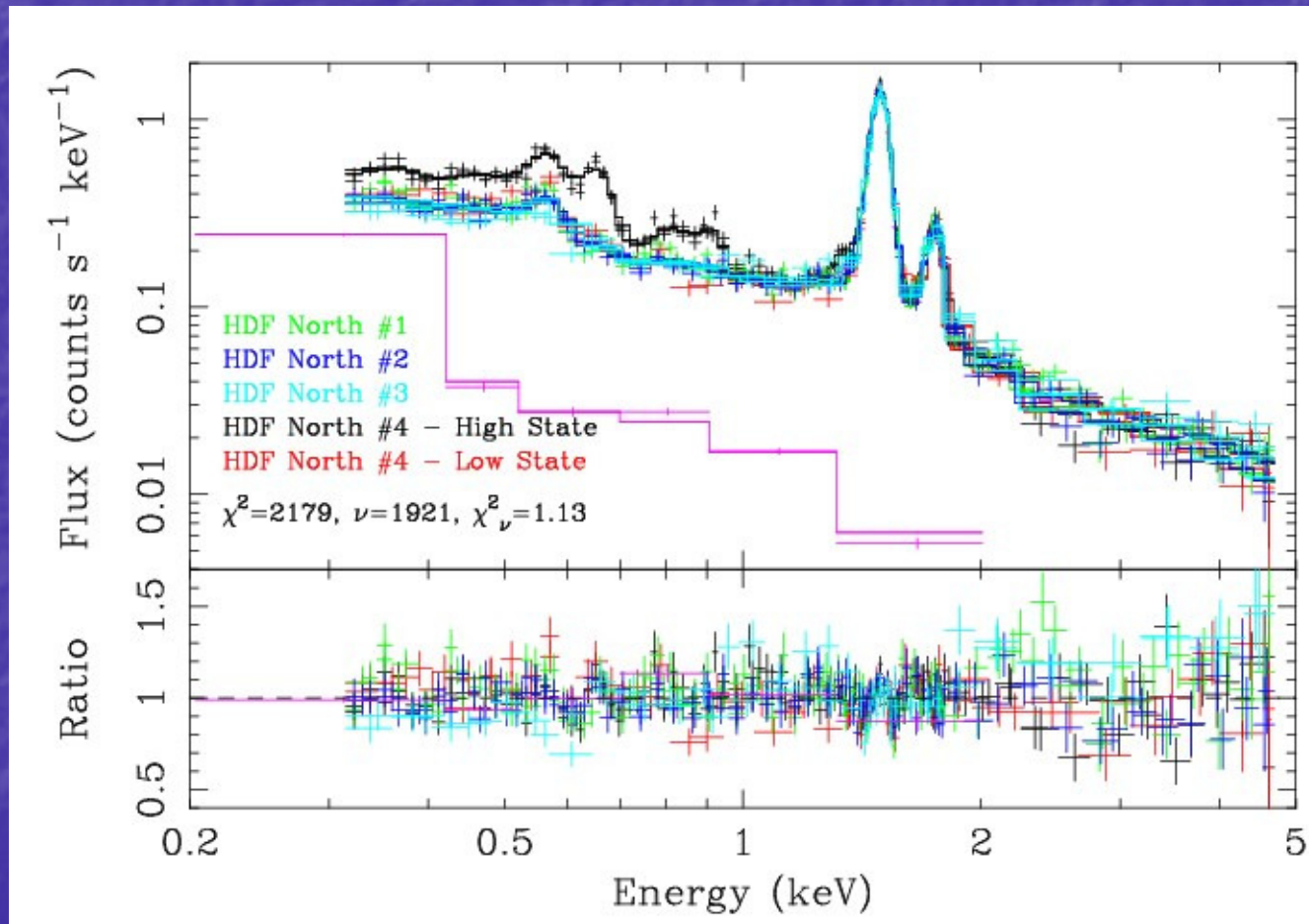
Fitted spectra from the observation of Abell 1795 in ten annuli. Only the XMM-Newton data are included in the fit. Note that Xspec V12 is required for the fitting.

Step 4 – Fit the Spectrum

Fitted spectra from the observation of Abell 1795 in ten annuli along with the RASS spectrum. The upper plot shows the result before the RASS data were used to constrain the cosmic background. The bottom plot shows the fit after the RASS data were used.



Step 4 – Fit the Spectrum

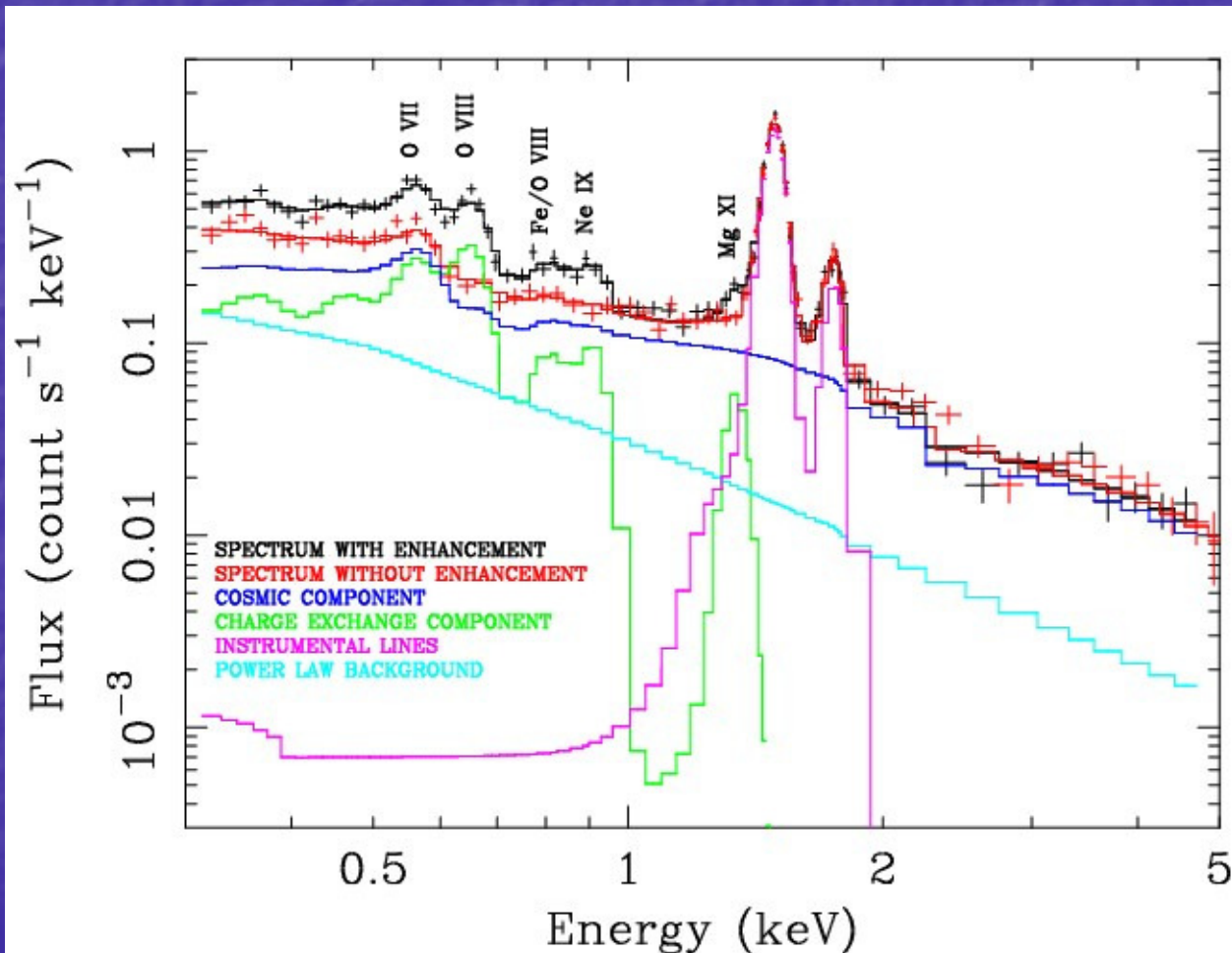


Watch out for SWCX contamination!

Plotted is the fitted spectrum of the Hubble Deep Field North with four separate observations one of which is separated into two parts. Also plotted is the RASS spectrum for the region.

The black curve shows the SWCX contamination.

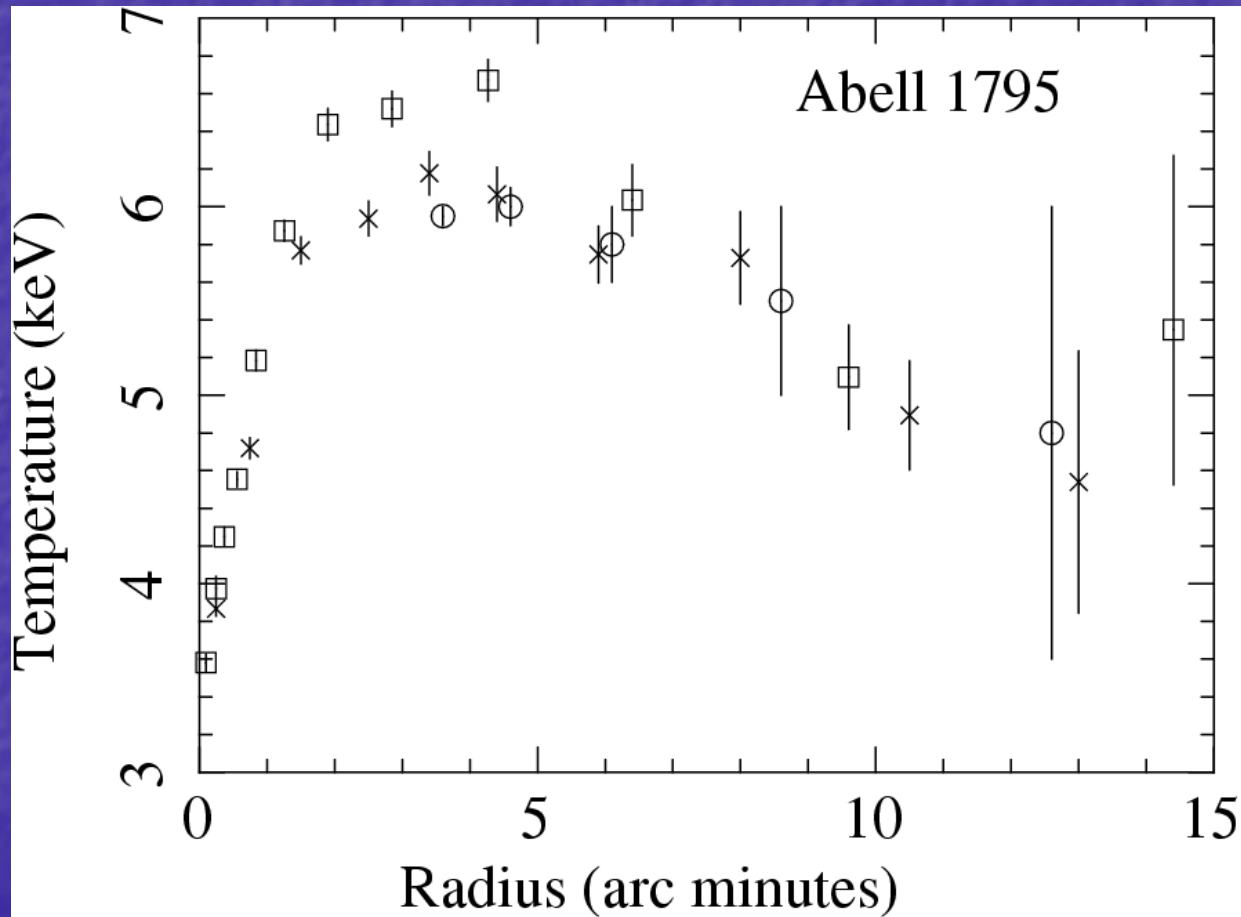
Step 4 – Fit the Spectrum



Plotted is the unfolded fitted spectrum of the Hubble Deep Field North with and without the SWCX contamination.

The strong OVII and OVIII emission can clearly significantly affect observations of extended sources and the diffuse background.

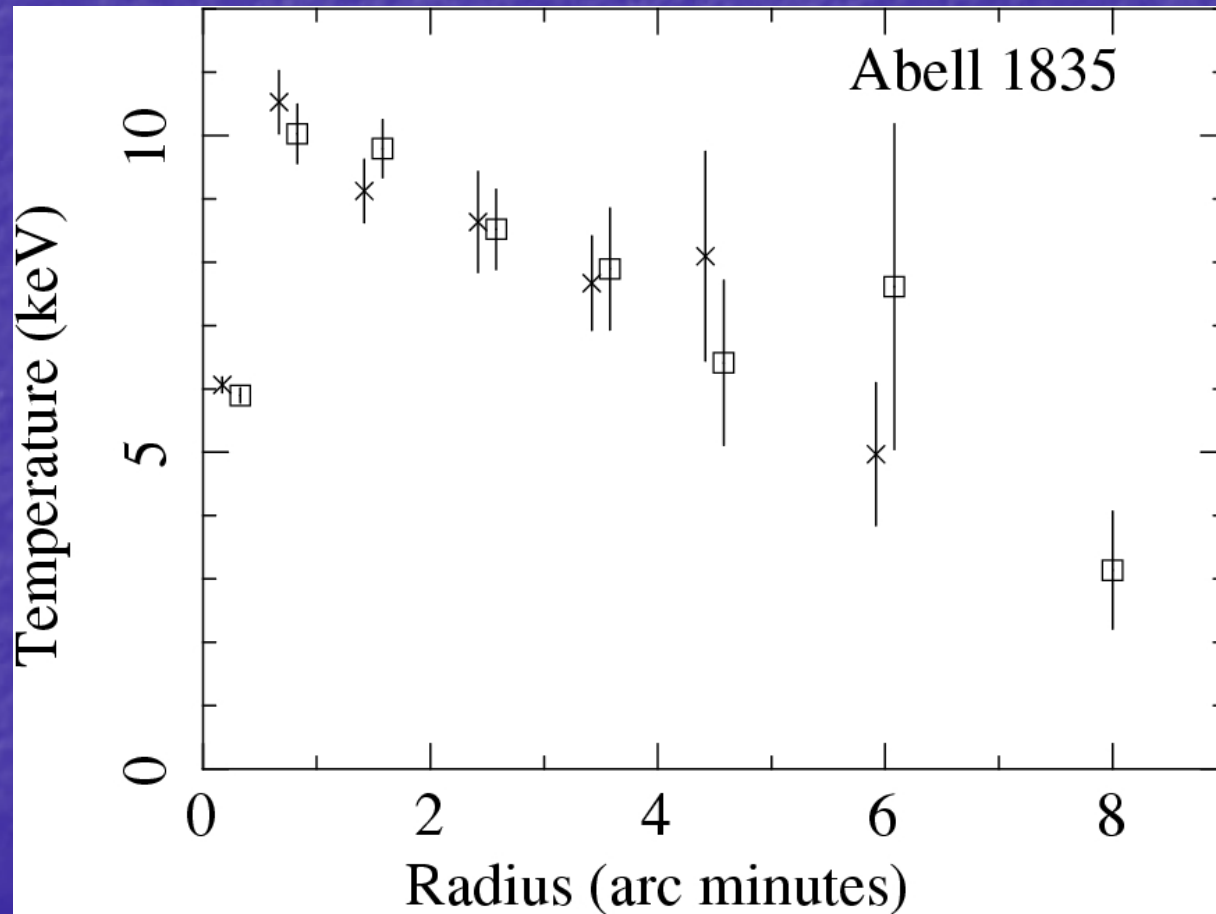
Examples



Watch out for discrepancies between XMM-Newton and Chandra data.

Temperature radial profile for A1795 from Chandra (squares), XMM-ESAS (crosses) and Nevalainen et al. (circles).

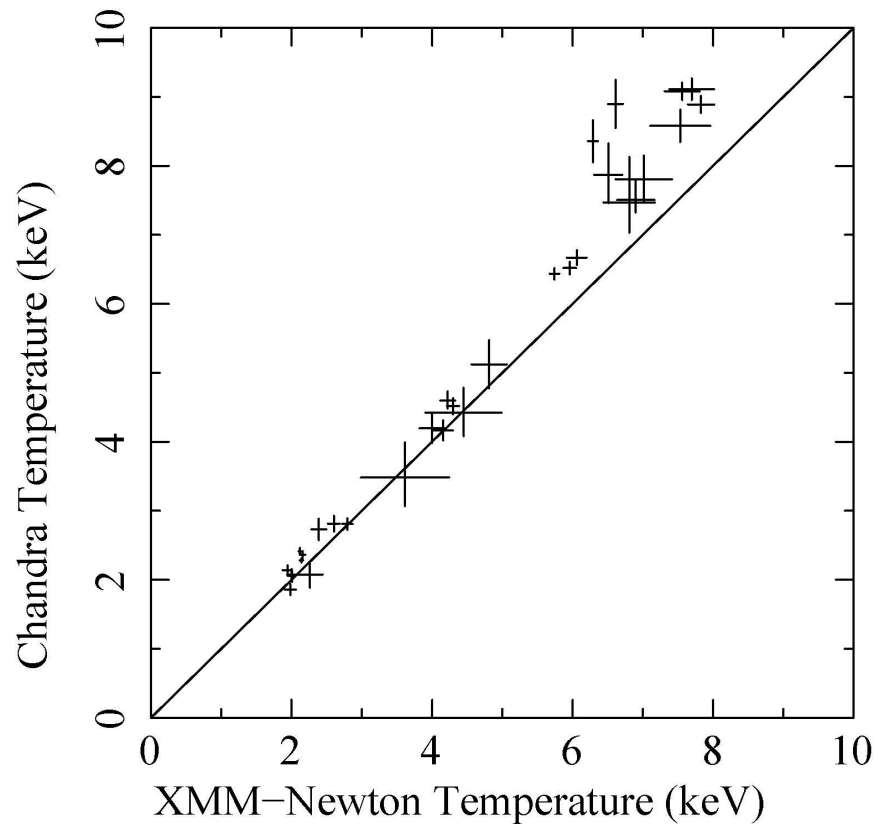
Examples



As a minimum requirement, the XMM-ESAS processing of the two observations of Abell 1835 yield the same results.

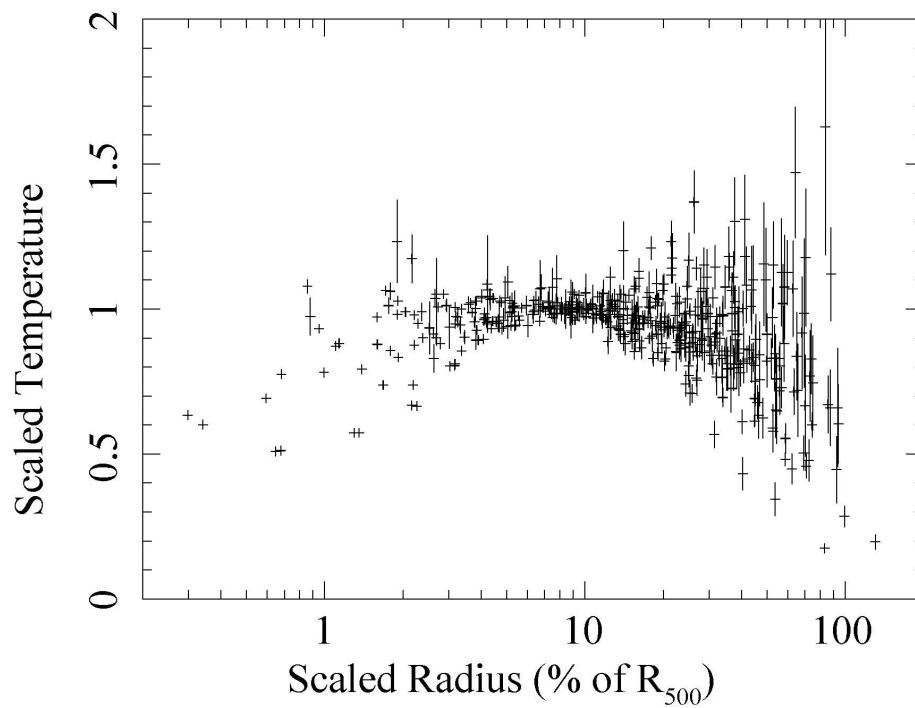
Temperature radial profiles for A1835 from two separate observations.

Examples



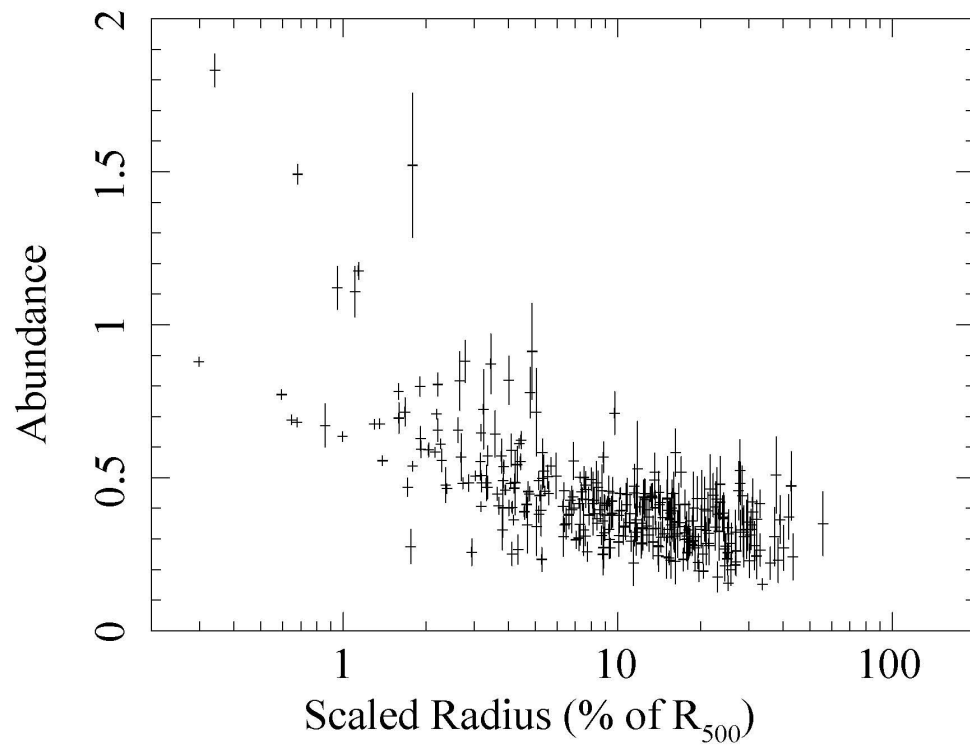
Comparison of Chandra and XMM-Newton fitted temperatures in the 1.5' – 6' region. Chandra data are from Vikhlinin et al. 2005.

Examples



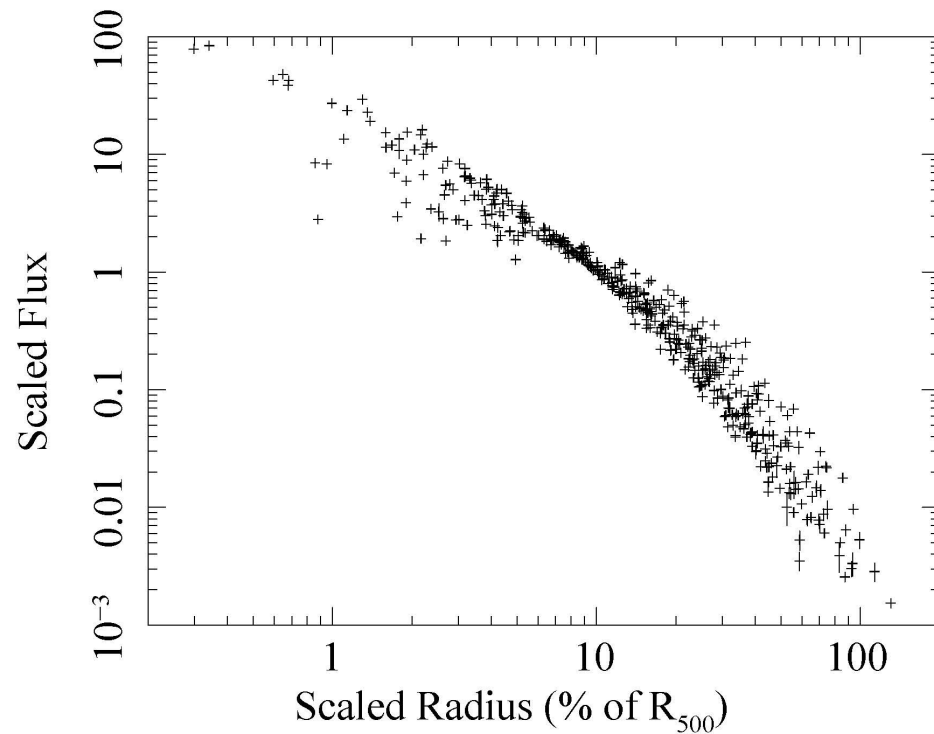
Temperature profiles
from a sample of 70
clusters observed by
XMM-Newton.

Examples



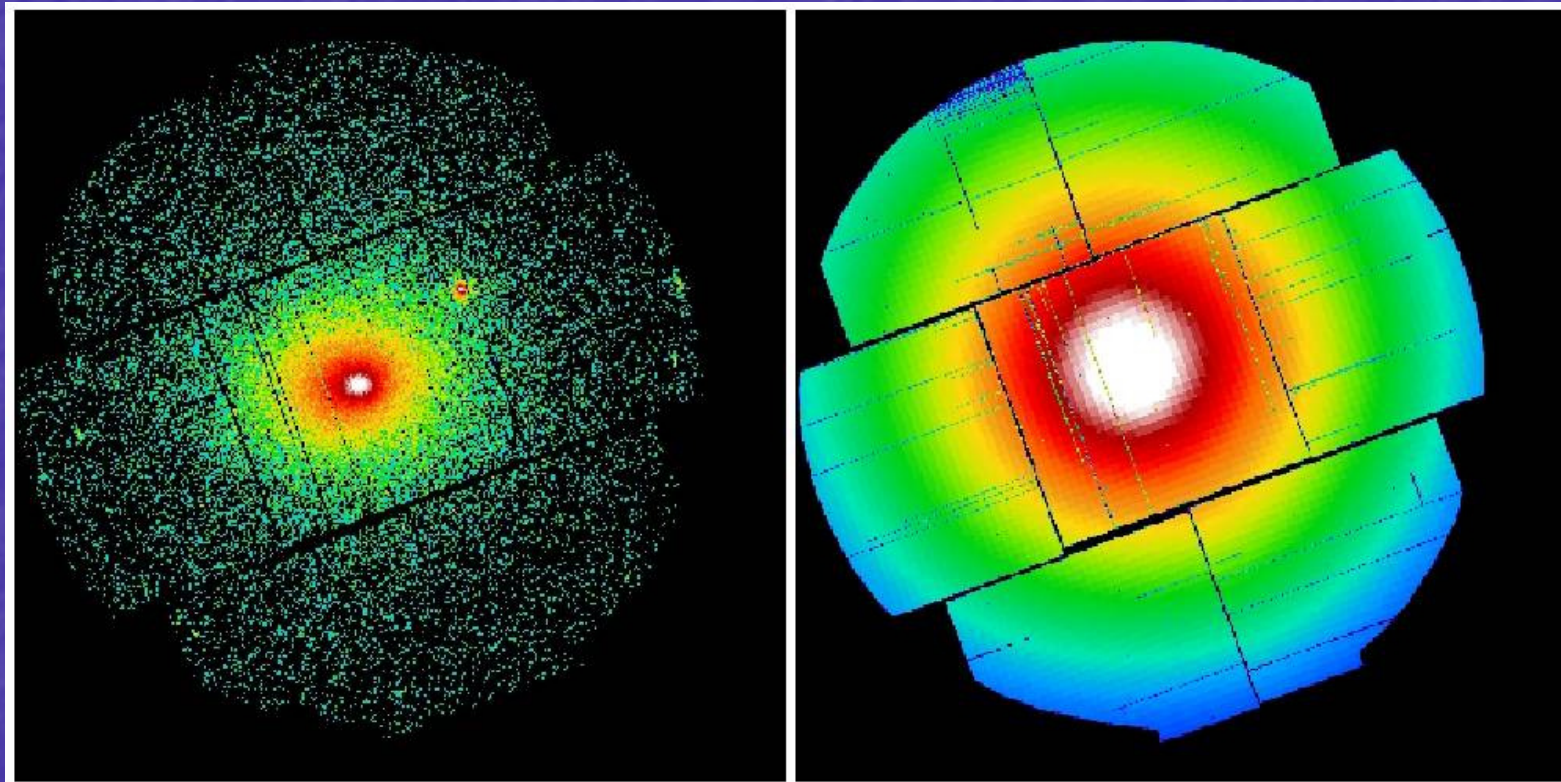
Abundance profiles
from a sample of 70
clusters observed by
XMM-Newton.

Examples



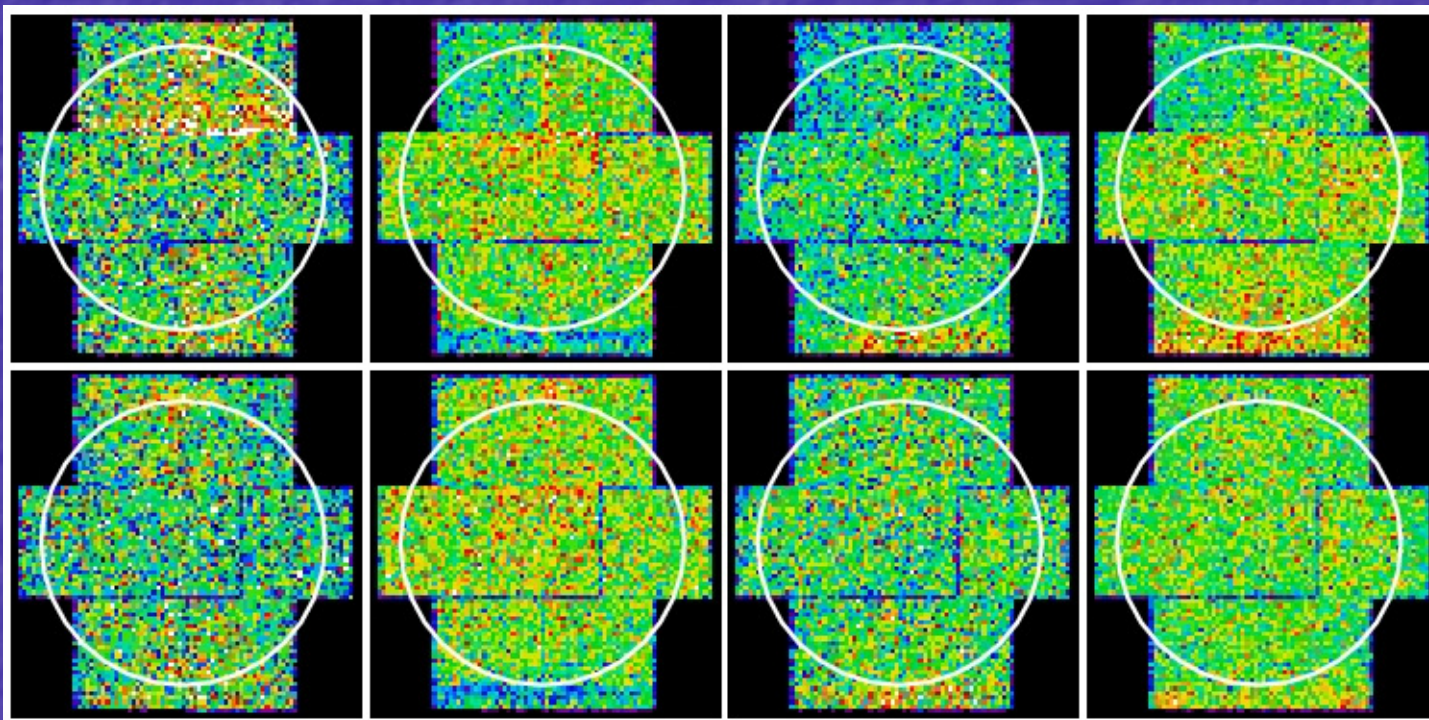
Flux profiles from
a sample of 70
clusters observed
by XMM-Newton.

Images



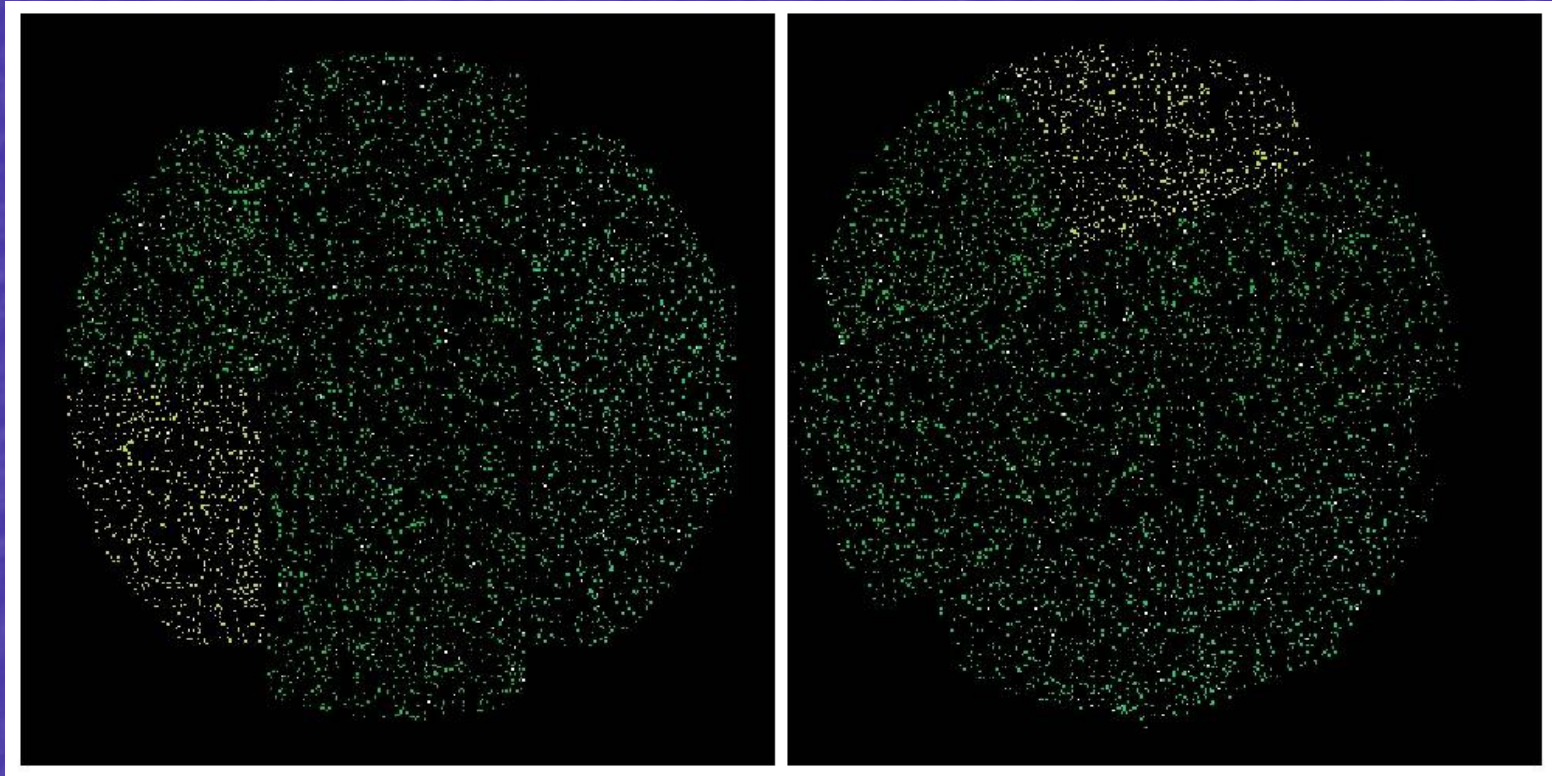
Count and exposure images of Abell 1795. Created from SAS tasks.

Images



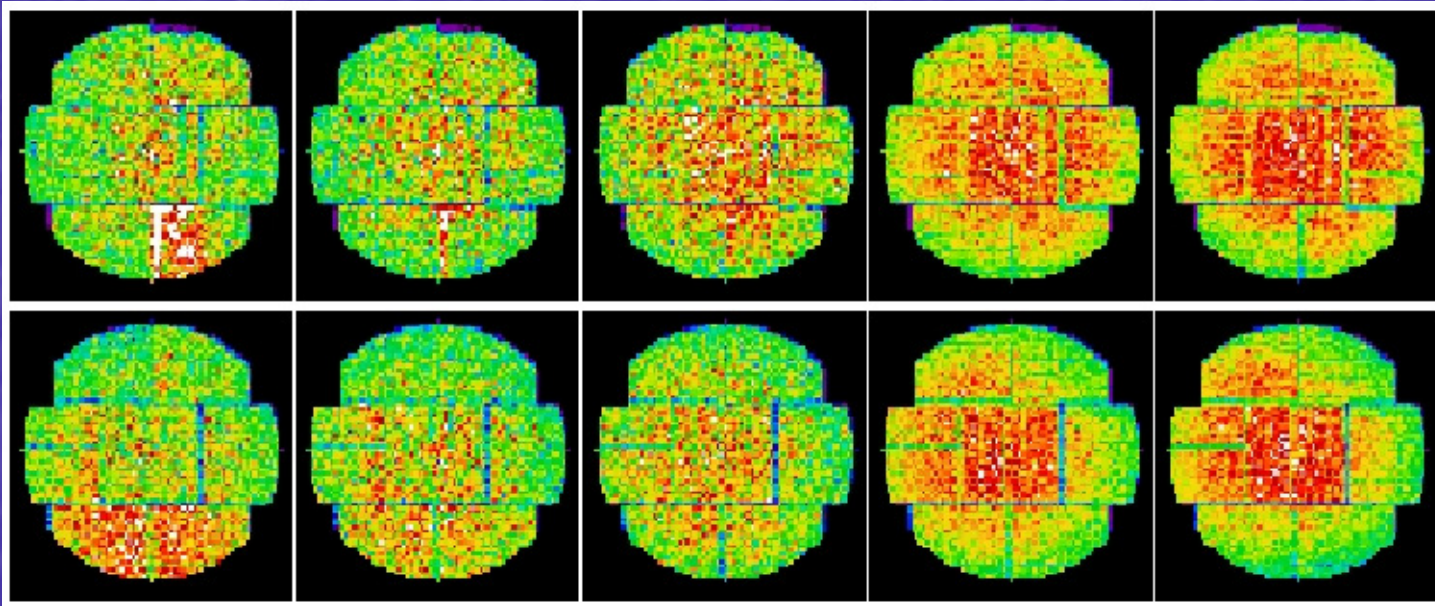
Filter wheel closed particle background images in various energy bands for the MOS1 (upper) and MOS2 (lower) detectors. From left to right, 0.3-0.75 keV, 0.75-1.25 keV, 1.25-2.0 keV, and 2.0-8.0 keV. These serve as the basis for creating model particle background maps.

Images



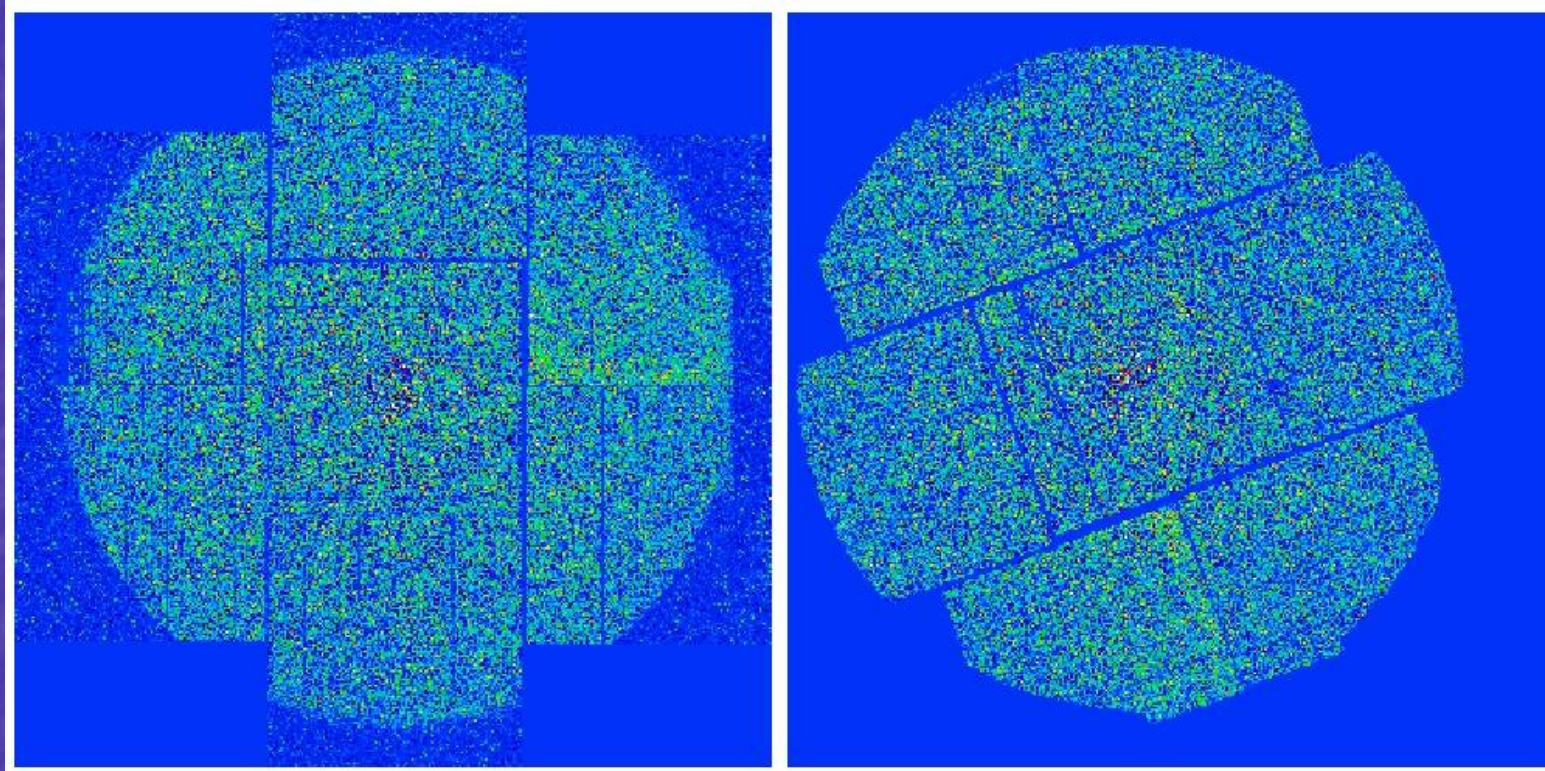
Particle background image of Abell 1795. The images are created in detector coordinates first and then reprojected into sky coordinates. This requires both a reflection and rotation.

Images



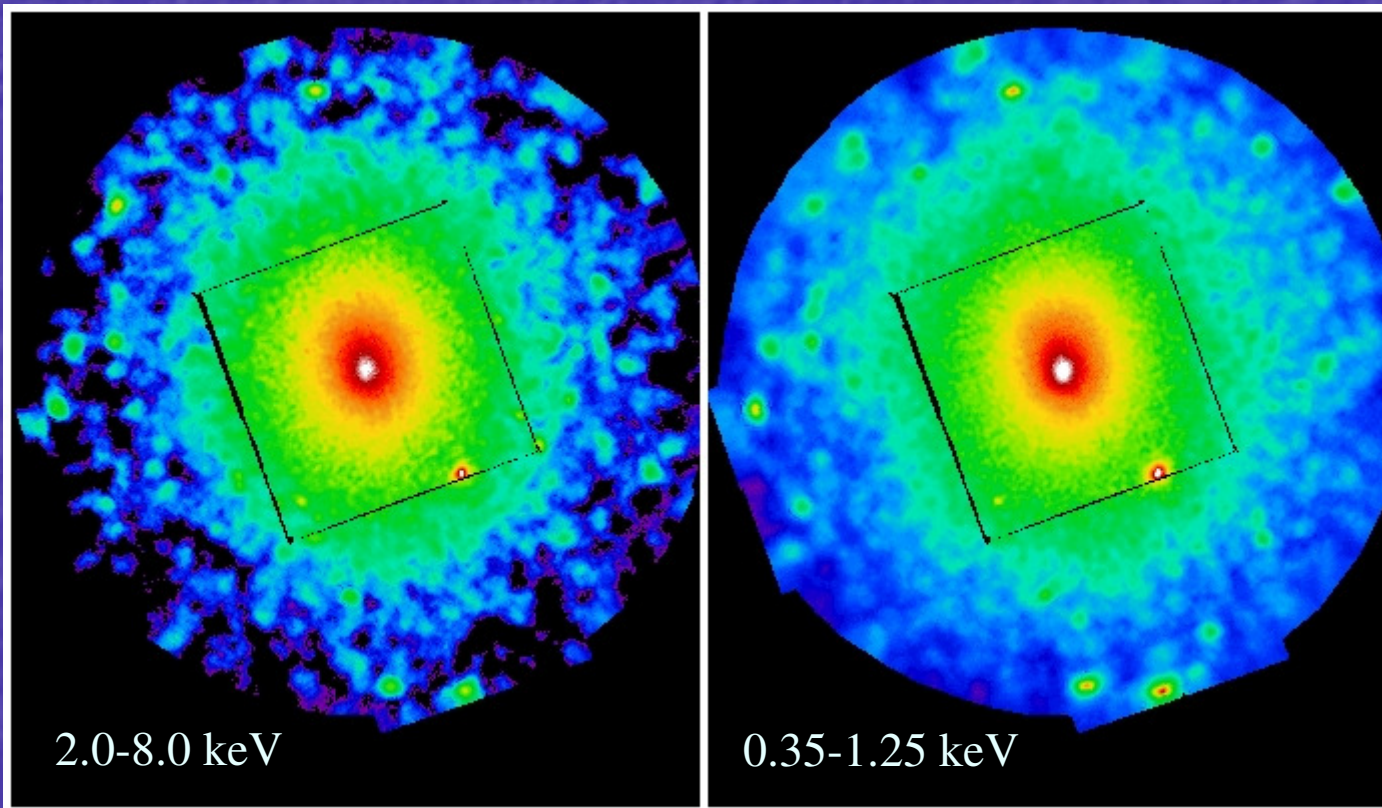
Soft proton background images in various energy bands for the MOS1 (upper) and MOS2 (lower) detectors. From left to right, 0.3-0.75 keV, 0.75-1.25 keV, 1.25-2.0 keV, 2.0-4.0 keV, and 4.0-8.0 keV. Created by Kuntz from archived data sets. Note the variation in spatial distribution.

Images



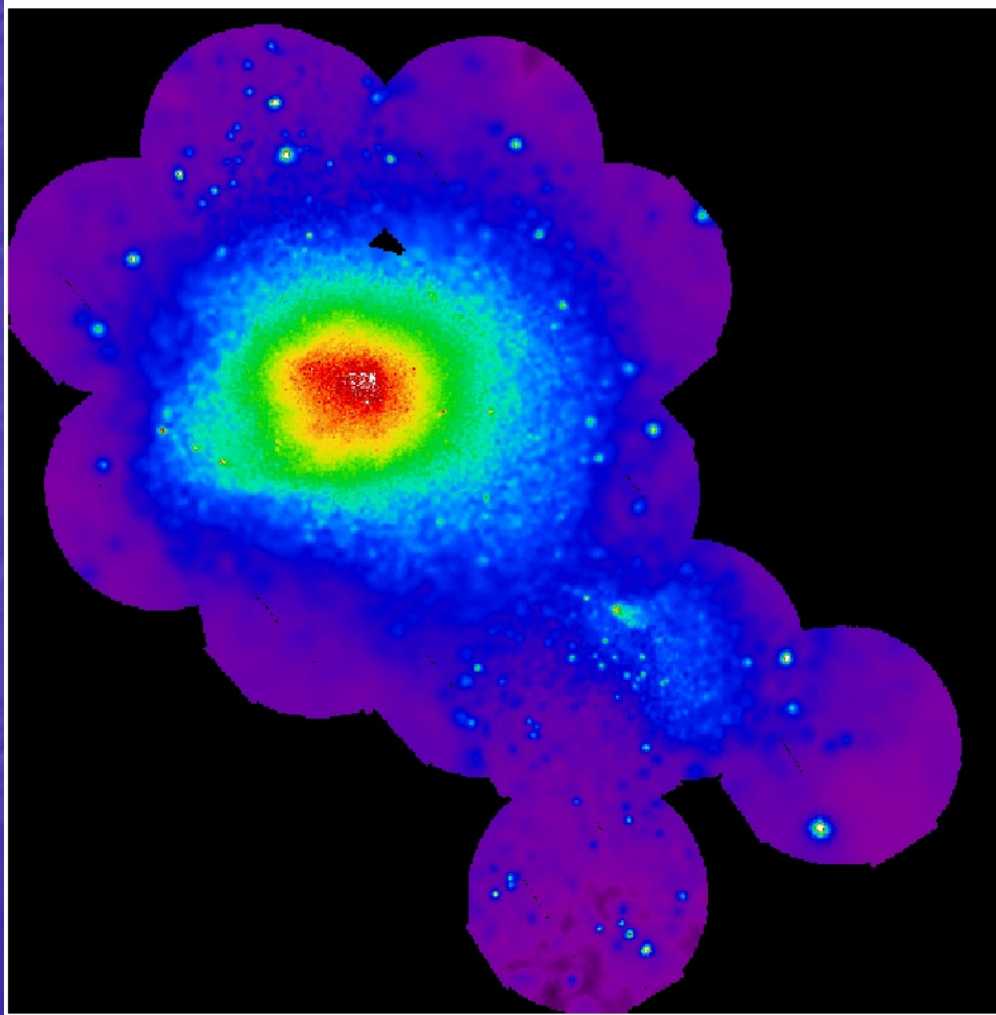
Soft proton background image of Abell 1795. The image on the left is again in detector coordinates and the image on the right is after recasting into sky coordinates and clipping.

Background Subtracted and Exposure Corrected Images



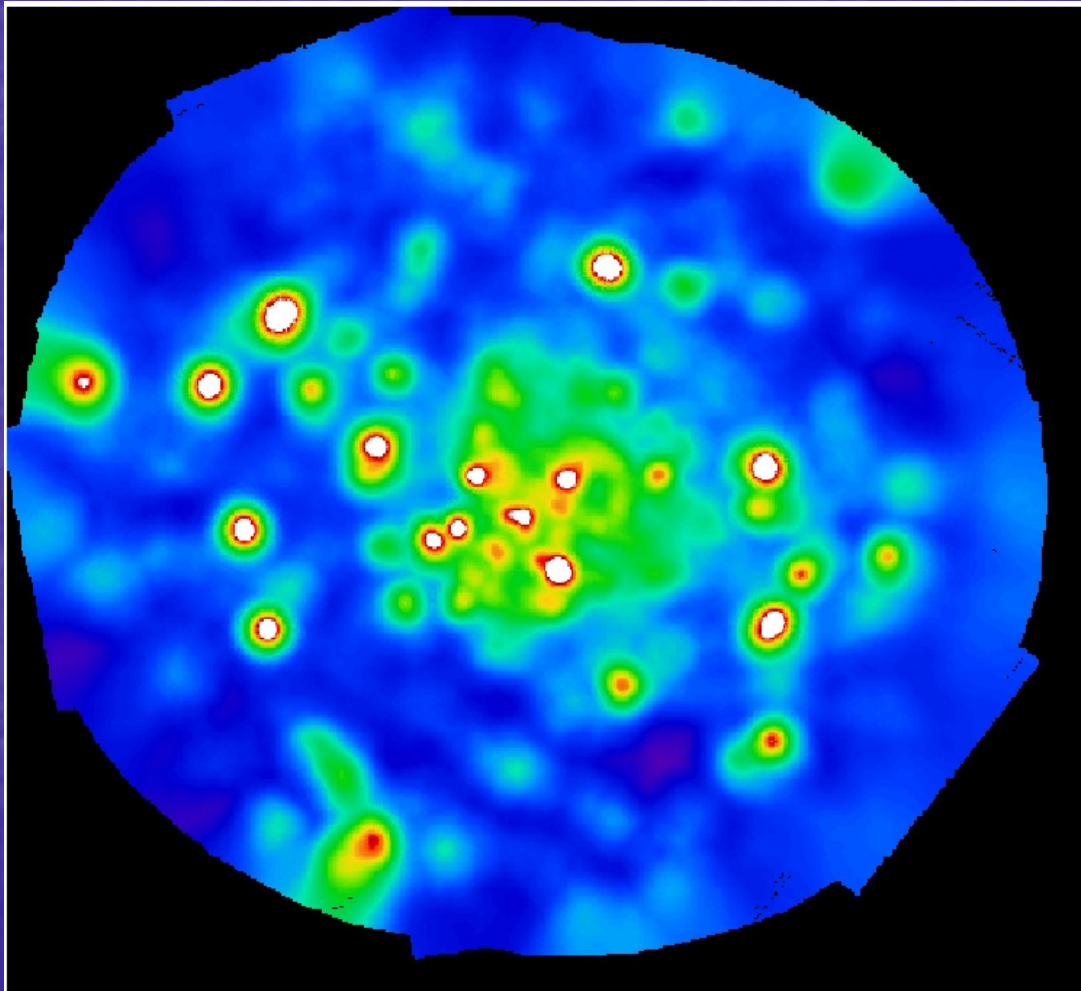
Background subtracted and exposure corrected images of Abell 1795

Mosaicked Images



Mosaic of Coma
Cluster observations.

Mosaicked Images



Mosaic of M101
observations.